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CONCERNING A FILING UNDER 35 U.S.C. 371**

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U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5)

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INTERNATIONAL APPLICATION NO.  
PCT/AU99/00872

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12 October 1999

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12 October 1998

**TITLE OF INVENTION**

A Method of Modulating Ion Channel Functional Activity

**APPLICANT(S) FOR DO/EO/US**

Graeme COX, Gary EWART and Peter GAGE

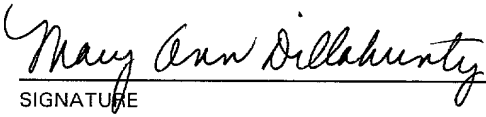
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and the PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
  - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ has been transmitted by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
  - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
  - b. ☐ have been transmitted by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An unexecuted oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

**Items 11. to 16. below concern other document(s) or information included:**

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.  
☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:

PCT Request, International Search Report, International Preliminary Examination Report, Statement Under C.F.R. §1.821(f), diskette containing sequence listing, hard copy of sequence listing

U.S. APPLICATION NO. (if known) (see 37 CFR 1.50) Unassigned <b>097807277</b>		INTERNATIONAL APPLICATION NO. PCT/AU99/00872		ATTORNEY'S DOCKET NUMBER 032505-010	
17. <input checked="" type="checkbox"/> The following fees are submitted:				CALCULATIONS	PTO USE ONLY
<b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b>  Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO ..... \$1,000.00 (960)  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO ..... \$860.00 (970)  International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO ..... \$710.00 (958)  International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) ..... \$690.00 (956)  International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) ..... \$100.00 (962)					
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>				\$ 1,000.00	
Surcharge of \$130.00 (154) for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492(e)). 20 <input type="checkbox"/> 30 <input type="checkbox"/>				\$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	54 -20 =	34	X\$18.00 (966)	\$ 612.00	
Independent Claims	5 -3 =	2	X\$80.00 (964)	\$ 160.00	
Multiple dependent claim(s) (if applicable)			+ \$270.00 (968)	\$ 0.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				\$ 1,772.00	
Reduction for 1/2 for filing by small entity, if applicable (see below).				\$ -886.00	-
<b>SUBTOTAL =</b>				\$ 886.00	
Processing fee of \$130.00 (156) for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492(f)). 20 <input type="checkbox"/> 30 <input type="checkbox"/>				\$	
<b>TOTAL NATIONAL FEE =</b>				\$ 886.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 (581) per property +				\$ 0.00	
<b>TOTAL FEES ENCLOSED =</b>				\$ 886.00	
				Amount to be: refunded	\$
				charged	\$
a. <input checked="" type="checkbox"/> Small entity status is hereby claimed. b. <input checked="" type="checkbox"/> A check in the amount of \$ <u>886.00</u> to cover the above fees is enclosed. c. <input type="checkbox"/> Please charge my Deposit Account No. <u>02-4800</u> in the amount of \$ _____ to cover the above fees. A duplicate copy of this sheet is enclosed. d. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>02-4800</u> . A duplicate copy of this sheet is enclosed.					
<b>NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>					
SEND ALL CORRESPONDENCE TO:  Mary Ann Dillahunt, Esq. BURNS, DOANE, SWECKER & MATHIS, L.L.P. P.O. Box 1404 Alexandria, Virginia 22313-1404 (650)622-2300					
 SIGNATURE					
Mary Ann Dillahunt NAME					
<u>34,576</u> REGISTRATION NUMBER					

09/807277

JC02 Rec'd PCT/PTO 11 APR 2001

Patent

Attorney's Docket No. 032505-010

#5/a

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of )  
)  
Graeme COX et al. ) Group Art Unit: Unassigned  
)  
Application No.: Unassigned ) Examiner: Unassigned  
)  
Filed: Herewith )  
)  
For: A METHOD OF MODULATING )  
ION CHANNEL FUNCTIONAL )  
ACTIVITY )

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Prior to examination or calculation of filing fee, please amend the subject  
application as follows:

IN THE SPECIFICATION:

Please amend the specification by inserting before the first line the sentence: -- This  
application is a national phase of PCT/AU99/00872 which was filed on October 12, 1999,  
and was published in English. --

IN THE CLAIMS:

Kindly replace claims 3, 6, 7, 16, 17, 24, 32 and 44, and add new claims 50-54, as follows.

3. (Amended) The method according to claim 1 wherein said HIV functional activity is HIV replication.
6. (Amended) The method according to claim 1 wherein said agent is an amiloride analogue or functional equivalent thereof.
7. (Amended) The method according to claim 6 wherein said amiloride analogue comprises a substitution of the amino group at the 5-position of the pyrazine ring or functional equivalent thereof.
16. (Amended) The method according to claim 12 wherein said agent is an amiloride analogue or functional equivalent thereof.
17. (Amended) The method according to claim 16 wherein said amiloride analogue comprises a substitution of the amino group at the 5-position of the pyrazine ring or functional equivalent thereof.

24. (Amended) Use according to claim 22 wherein said agent is an amiloride analogue or functional equivalent thereof.

32. (Amended) The method according to claim 30 wherein said amiloride analogue comprises a substitution of the amino group of the 5-position of the pyrazine ring or functional equivalent thereof.

44. (Amended) A pharmaceutical composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity said composition comprising an agent as defined in according with claim 1 and one or more pharmaceutical acceptable carriers and/or diluents.

50. (New) The method according to Claim 5 wherein said agent is an amiloride analogue or functional equivalent thereof.

51. (New) The method according to Claim 15 wherein said agent is an amiloride analogue or functional equivalent thereof.

52. (New) Use according to Claim 23 wherein said agent is an amiloride analogue or functional equivalent thereof.

53. (New) The method according to Claim 31 wherein said amiloride analogue comprises a substitution of the amino group of the 5- position of the pyrazine ring or functional equivalent thereof.

54. (New) A pharmaceutical composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity said composition comprising an agent as defined in according with Claim 37 and one or more pharmaceutical acceptable carriers and/or diluents.

**REMARKS**

Entry of the foregoing amendment to the Specification is requested to comply with the requirements of 37 C.F.R. 1.78(a)(2). The claims of the subject application have been amended to avoid multiple dependency. Favorable consideration of the application is respectfully requested.

Respectfully submitted,

BURNS, DOANE, SWECKER & MATHIS, L.L.P.

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Date: April 10, 2001

**Attachment to Preliminary Amendment dated April 10, 2001**

**Marked-up Claims 3, 6, 7, 16, 17, 24, 32 and 44**

3. (Amended) The method according to claim [3] 1 wherein said HIV functional activity is HIV replication.
6. (Amended) The method according to [any one of claims 1 to 5] claim 1 wherein said agent is an amiloride analogue or functional equivalent thereof.
7. (Amended) The method according to claim 6 wherein said amiloride analogue comprises a substitution of the amino group at the 5- position of the pyrazine ring [of] or functional equivalent thereof.
16. (Amended) The method according to [any one of claims 12 to 15] claim 12 wherein said agent is an amiloride analogue or functional equivalent thereof.
17. (Amended) The method according to claim 16 wherein said amiloride analogue comprises a substitution of the amino group at the 5-position of the pyrazine ring [of] or functional equivalent thereof.
24. (Amended) Use according to claim 22 [or 23] wherein said agent is an amiloride analogue or functional equivalent thereof.
32. (Amended) The method according to [any one of claims 30 or 31] claim 30 wherein said amiloride analogue comprises a substitution of the amino group of the 5- position of the pyrazine ring or functional equivalent thereof.



44. (Amended) A pharmaceutical composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity said composition comprising an agent as defined in accordance with [any one of claims 1 to 21] claim 1 and one or more pharmaceutical acceptable carriers and/or diluents.

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## A METHOD OF MODULATING ION CHANNEL FUNCTIONAL ACTIVITY

### FIELD OF THE INVENTION

5 The present invention relates generally to a method of retarding, reducing or otherwise inhibiting viral functional activity and, more particularly, to a method of reducing, retarding or otherwise inhibiting viral functional activity by down-regulating Vpu ion channel functional activity. Even more particularly, the present invention provides a method of treating HIV infection or AIDS by inhibiting Vpu ion channel mediated HIV  
10 replication.

### BACKGROUND OF THE INVENTION

Bibliographic details of the publications alphabetically referred to in this specification are  
15 collected at the end of the description.

Currently, no single treatment method is completely effective against HIV infections. Combination therapies, using drugs that target a number of different aspects of HIV replication, have proven to be the most effective way of ameliorating AIDS symptoms and  
20 prolonging life expectancy (Barry *et al*, 1998; Deeks, 1998; Miles, 1997; Miles, 1998; Moyle *et al*, 1998; Rachlis and Zarowny, 1998; Vell *et al*, 1997; Volberding and Deeks, 1998; and Volberdin, 1998). For example, a measure of success has been achieved with drugs targeting the viral reverse transcriptase and protease enzymes (Miller and Sarver, 1997; Mitsuya, 1992; Moore, 1997; and Thomas and Brady, 1997).

25

The protein Vpu forms an ion channel encoded by HIV and has a number of known roles in the virus life cycle including down-regulation of cell surface expression of the CD4 virus receptor molecule, control of the exit of gp160 from the endoplasmic reticulum and its delivery to the cell surface and regulation of virion budding from the cell surface  
30 membrane. In the absence of Vpu, HIV replication has been shown to be severely retarded in monocytes and macrophages (Balliet *et al*, 1994; and Westervelt *et al*, 1992).

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Nevertheless, Vpu has been labelled as an "accessory" protein of HIV because none of its known functions appear to be essential for virus replication *in vitro*.

To improve the prospect of treating and preventing HIV infection, there is an on-going need to identify molecules capable of inhibiting various aspects of the HIV life cycle. In work leading up to the present invention, the inventors have surprisingly determined that despite current dogma, viral replication (and in particular HIV replication) can be retarded by inhibiting or otherwise down-regulating Vpu ion channel functioning. Further, the inventors have also determined that although the drug amiloride has no effect on HIV replication, amiloride analogues, in which the H<sub>2</sub>N group located at the 5-position of the pyrazine has been substituted, inhibit Vpu function and thereby inhibit the continuation of the HIV life cycle.

#### SUMMARY OF THE INVENTION

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The subject specification contains nucleotide and amino acid sequence information prepared using the programme PatentIn Version 2.0, presented herein after the bibliography. Each nucleotide or amino acid sequence is identified in the sequence listing by the numeric indicator <210> followed by the sequence identifier (e.g. <210> 1, <210> 2, etc). The length, type of sequence (DNA, protein (PRT), etc) and source organism for each nucleotide or amino acid sequence are indicated by information provided in the numeric indicator fields <211>, <212> and <213>, respectively. Nucleotide and amino sequences referred to in the specification are defined by the information provided in numeric indicator field <400> followed by the sequence identifier (e.g. <400> 1, <400> 2, etc).

One aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting the functional activity of a virus, which virus has infected a mammalian host cell, said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate a membrane ion channel  
5 functional activity of said host cell.

Another aspect of the present invention more particularly provides a method of reducing, retarding or otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian host cell, said method comprising administering to said mammal an effective  
10 amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of said host cell.

Still another aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting HIV replication, which HIV has infected a mammalian host cell, said  
15 method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of said host cell.

Yet another aspect of the present invention provides a method of reducing, retarding or  
20 otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian macrophage, said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of said macrophage.

Still yet another aspect of the present invention provides a method of reducing, retarding  
25 or otherwise inhibiting HIV replication, which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of an amiloride analogue, or functional equivalent thereof, for a time and under conditions sufficient to inhibit Vpu ion channel functional activity.

A further aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting HIV replication, which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of HMA or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel mediation of HIV replication.

Another further aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting HIV replication which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of DMA or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel mediation of HIV replication.

Still another further aspect provides a method for the treatment and/or prophylaxis of HIV infection or AIDS in a mammal said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of an HIV infected mammalian host cell, wherein said Vpu functional activity down-regulation reduces, retards or otherwise inhibits the functional activity of said HIV.

Still yet another further aspect provides a method for the treatment and/or prophylaxis of HIV infection or AIDS in a mammal said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of an HIV infected mammalian host cell, wherein said Vpu functional activity down-regulation reduces, retards or otherwise inhibits HIV replication.

Another aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting membrane ion channel functional activity in a subject said method comprising administering to said subject an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit membrane ion channel functional activity.

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Yet another aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting Vpu ion channel functional activity in a mammal said method comprising administering to said mammal an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion  
5 channel functional activity.

Still another aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting Vpu ion channel mediation of HIV replication in a mammal said method comprising administering to said mammal an effective amount of an amiloride  
10 analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel functional activity.

Still yet another aspect of the present invention provides an agent useful for reducing, retarding or otherwise inhibiting Vpu ion channel functional activity as hereinbefore  
15 defined.

Still another aspect of the present invention provides a composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity comprising an agent as hereinbefore defined and one or more pharmaceutically acceptable carriers and/or  
20 diluents.

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**BRIEF DESCRIPTION OF THE DRAWINGS**

**Figure 1** is a schematic representation of plasmids used for expression of Vpu in *E. coli*. **A.** The amino acid sequence (<400>1) encoded by the *vpu* open reading frame (ORF) generated by PCR from an HIV-1 strain HXB2 cDNA clone. The *vpu* ORF was cloned in-frame at the 3' end of the GST gene in p2GEX to generate p2GEXVpu (**B**). It was subsequently cloned into pPL451 to produce the plasmid pPL+Vpu (**C**).

**Figure 2** is a photographic representation of the expression and purification of Vpu in *E. coli*. **A.** Western blotting after SDS-PAGE was used to detect expressed Vpu in *E. coli* extracts. **Lanes 1-4** contain samples, at various stages of purity, of Vpu expressed from p2GEXVpu: **lane 1**, GST-Vpu fusion protein isolated by glutathione-agarose affinity chromatography; **lane 2**, Vpu liberated from the fusion protein by treatment with thrombin; **lane 3**, Vpu purified by HPLC anion exchange chromatography; **lane 4**, Vpu after passage through the immunoaffinity column. **Lanes 5 and 6**, membrane vesicles prepared from 42°C induced cells containing pPL+Vpu or pPL451, respectively. **B.** Silver stained SDS-PAGE gel: **lane 1**, Vpu purified by HPLC anion exchange chromatography; **lane 2**, Vpu after passage through the immunoaffinity column.

**Figure 3** is a graphical representation of ion channel activity observed after exposure of lipid bilayers to aliquots containing purified Vpu. In **A** and **B**, the CIS chamber contained 500mM NaCl and the TRANS chamber contained 50mM NaCl; both solutions were buffered at pH 6.0 with 10 mM MES. **B** shows a current versus voltage curve generated from data similar to that shown in **A**.

**Figure 4** is a photographic representation of bacterial cross-feeding assays. For all plates, the Met<sup>-</sup>, Pro<sup>-</sup> auxotrophic strain was used to seed a soft agar overlay. Plates **A** and **B** contain minimal drop-out medium minus proline; in plate **C** the medium was minus methionine. To control for viability of the cells in the background lawn, the discs labelled **P** and **M** contained added proline or methionine, respectively. The discs labelled **C** and **V** were inoculated with Met<sup>+</sup>, Pro<sup>+</sup> *E. coli* cells containing the plasmids pPL451 or

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pPL + Vpu, respectively. Plates were incubated at 37°C (A and C) or 30°C (B) for two days and photographed above a black background with peripheral illumination from a fluorescent light located below the plate. The images were recorded on a Novaline video gel documentation system. Light halos around the discs labelled P or M on all plates and  
5 around the disc labelled V on plate A indicate growth of the background lawn strain.

**Figure 5** is a graphical representation of the screening of drugs for potential Vpu channel blockers. The photograph shows a section of a minimal medium-lacking adenine - agarose plate onto which a lawn of XL-1-blue *E. coli* cells containing the Vpu expression plasmid  
10 pPLVpu has been seeded. Numbers 6-11 are located at the sites of application of various drugs being tested, which were applied in 3µl drops and allowed to soak into the agarose. The plate was then incubated at 37°C for 48hr prior to being photographed. The background grey shade corresponds to areas of no bacterial growth. The bright circular area around "10" represents bacterial cell growth as a result of application of adenine at  
15 that location (positive control). The smaller halo of bacterial growth around "9" is due to the application of 5-(N,N-hexamethylene)-amiloride at that location.

**Figure 6** is a graphical representation of the inhibition of Vpu ion channel activity by 5-(N,N-hexamethylene)-amiloride (HMA) in planar lipid bilayers. The three traces  
20 represent typical Vpu channel activity observed in the presence of the indicated concentrations of HMA. The solid line indicates the zero current level. Mean currents ( $\pm$  variance), calculated for continuous channel recordings of at least 30 seconds duration, are plotted in the graph for each of the three drug concentrations.

25 **Figure 7** is a graphical representation of the effect of HMA on HIV virion production in monocytes and monocyte-derived macrophages. HIV in culture supernatants was assayed at various days post-infection by detection of p24 antigen using a quantitative ELISA method. Solid black bars represent HIV-infected cells exposed to 10µM HMA. Hatched bars are control cells not exposed to drug.



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Figure 8 is a schematic representation of the chemical formula of amiloride, HMA and DMA:  $R=H_2N$ , amiloride:  $R=(CH_3)_2N$ , DMA;  $R=(CH_2)_6N$ , HMA.

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**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The present invention is predicated, in part, on the surprising determination that the replication of viruses which cause a host cell to express a Vpu ion channel, in particular HIV, can be retarded by inhibiting the functioning of this ion channel. Further, although amiloride has no effect on HIV replication, amiloride analogues are able to inhibit the HIV life cycle by inhibiting Vpu ion channel functioning. This determination now permits the use of agents such as, but not limited to, amiloride analogues as anti-viral agents for the therapy and prophylaxis of viral conditions.

10 Accordingly, one aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting the functional activity of a virus, which virus has infected a mammalian host cell, said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate a  
15 membrane ion channel functional activity of said host cell.

Reference to "membrane ion channel" should be understood as a reference to a structure which transports ions across a membrane. The present invention extends to ion channels which may function by means such as passive, osmotic, active or exchange transport. The  
20 ion channel may be formed by intracellular or extracellular means. For example, the ion channel may be an ion channel which is naturally formed by a cell to facilitate its normal functioning. Alternatively, the ion channel may be formed by extracellular means.

Extracellular means would include, for example, the formation of ion channels due to introduced chemicals, drugs or other agents such as ionophores or due to the functional  
25 activity of viral proteins encoded by a virus which has entered a cell. Preferably, the ion channel of the present invention is an ion channel which results from the infection of a cell with HIV and, more particularly, the ion channel is formed by the HIV protein Vpu (referred to herein as a "Vpu ion channel").

30 The ion channels which are the subject of the present invention facilitate the transport of ions across membranes. Said membrane may be any membrane and is not limited to the

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outer cell wall plasma membrane. Accordingly, "membrane" encompasses the membrane surrounding any cellular organelle, such as the Golgi apparatus and endoplasmic reticulum, the outer cell membrane, the membrane surrounding any foreign antigen which is located within the cell (for example, a viral envelope) or the membrane of a foreign  
5 organism which is located extracellularly. The membrane is typically, but not necessarily, composed of a fluid lipid bilayer. The subject ion channel may be of any structure. For example, the Vpu ion channel is formed by Vpu which is an integral membrane protein encoded by HIV-1 which associates with, for example, the Golgi and endoplasmic reticulum membranes of infected cells. Reference hereinafter to "Vpu ion channels"  
10 should be read as including reference to all other ion channels.

Accordingly, the present invention more particularly provides a method of reducing, retarding or otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian host cell, said method comprising administering to said mammal an effective  
15 amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of said host cell.

Reference to "HIV" should be understood as a reference to any HIV strain and including homologues and mutants.  
20

Without limiting the present invention in any way, Vpu is a protein comprising approximately 80 amino acids with an N-terminal transmembrane anchor and a hydrophilic cytoplasmic C-terminal domain. The C-terminal domain typically comprises a 12 amino acid sequence that is conserved and contains two serine residues which are phosphorylated  
25 (Schubert *et al*, 1994 and Friberg *et al*, 1995). Vpu is an integral membrane protein encoded by HIV-1. It associates with the Golgi and endoplasmic reticulum membranes in infected cells, but has not been detected in the viral envelope nor in the plasma membrane of cells except when artificially over-expressed (Schubert *et al*, 1996a). without limiting the present invention in any way, Vpu has the capacity to form homo-oligomers, but the  
30 exact number of subunits in the native complex is not known. The secondary structure and tertiary fold of the cytoplasmic domain of Vpu has been determined by a combination

of NMR and CD spectroscopy and molecular dynamics calculations (Willbold *et al*, 1997) and reveals two  $\alpha$ -helices separated by a short flexible loop containing the phosphorylated serine residues. Recent structural data for the transmembrane domain (Wray *et al*, 1999) supports the theoretical prediction that the region is  $\alpha$ -helical and indicates a tilt angle of less than  $30^\circ$  to the bilayer normal. Two molecular dynamics simulation studies have been reported based on the assumption that oligomerisation produces a bundle of  $\alpha$ -helices that spans the membrane (Grice *et al*, 1997; and Moore *et al*, 1998). Both studies favour formation of a pentameric complex. However, using different initial conditions and restraint parameters, different conclusions as to the orientation of the individual helices in the complex were reached. Thus, the actual structure of the native Vpu complex remains to be determined.

In spite of the fact that Vpu has been shown by the inventors to form ion channels, prior to the advent of the present invention it was not known that ion channel formation by Vpu was a function which is critical to the life cycle of the HIV virus.

Reference to the "functional activity" of an ion channel should be understood as a reference to any one or more of the functions which an ion channel performs or is involved in. For example, the Vpu protein encoded ion channel, in addition to facilitating the transportation of  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Cl}^-$  and  $\text{PO}_4^{3-}$ , also plays a role in the degradation of the CD4 molecule in the endoplasmic reticulum. The Vpu protein encoded ion channel is also thought to play a role in mediating the HIV life cycle since inactivating this channel inhibits the HIV life cycle, in particular, the replication of HIV. However, the present invention is not limited to treating HIV infection via the mechanism of inhibiting the HIV life cycle and, in particular, HIV replication. Rather, the present invention should be understood to encompass any mechanism by which inhibiting Vpu ion channel functional activity acts to reduce, retard or otherwise inhibit HIV viability or functional activity. Said functional activity is preferably mediation of the replication of HIV. In this regard, reference to the "functional activity" of a virus should be understood as a reference to any one or more of the functions which a virus performs or is involved in. This includes, for

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example, viral replication and budding. Preferably, said functional activity is HIV replication.

Reference to the "HIV replication" should be understood to include any one or more  
5 stages or aspects of the HIV life cycle, such as inhibiting the assembly or release of HIV  
virions. Said Vpu mediation of HIV replication may be by direct or indirect means. Said  
Vpu mediation is by direct means if the Vpu ion channel interacts directly with HIV at any  
one or more of its life cycle stages. Said Vpu mediation is indirect if it acts on a molecule  
other than HIV which other molecule either directly or indirectly modulates any one or  
10 more aspects or stages of the HIV life cycle. Accordingly, the method of the present  
invention encompassess the mediation of HIV replication via the induction of a cascade of  
steps which lead to the mediation of any one or more aspects or stages of the HIV life  
cycle.

15 According to this preferred embodiment, the present invention provides a method of  
reducing, retarding or otherwise inhibiting HIV replication, which HIV has infected a  
mammalian host cell, said method comprising administering to said mammal an effective  
amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion  
channel functional activity of said host cell.

20

Reference to "down-regulating" ion channel functional activity, and in particular Vpu  
mediation of HIV replication should be understood as a reference to the partial or  
complete inhibition of any one or more aspects of said activity by both direct and indirect  
mechanisms. For example, a suitable agent may interact directly with a Vpu ion channel  
25 to prevent HIV replication or, alternatively, may act indirectly to prevent said replication  
by, for example, interacting with a molecule other than the Vpu ion channel wherein said  
other molecule interacts with and inhibits the activity of the Vpu ion channel.

The inhibition of ion channel functional activity may be achieved by any suitable method,  
30 which would be well known to those skilled in the art, including contacting a virally  
infected cell with a proteinaceous or non-proteinaceous molecule capable of blocking or

otherwise down-regulating functioning of the subject ion channel. Screening for molecules which block Vpu ion channel activity may be achieved for by any suitable method including, for example, the method disclosed in Example 11. It should also be understood that the down-regulation of ion channel functional activity may be achieved by transfecting  
5 a cell, such as the subject host cell, with a nucleic acid molecule which expresses a molecule capable of blocking or otherwise down-regulating functioning of the subject ion channel. Accordingly, reference to "agent" should be understood as a reference to any proteinaceous or non-proteinaceous molecule, including nucleic acid molecules, which directly or indirectly inhibit Vpu ion channel functional activity. Reference to an "agent"  
10 should be understood to include reference to functional equivalents and derivatives thereof of said agent.

Reference to a "mammalian host cell" infected with HIV should be understood as a reference to any cell which has been infected with HIV. This includes, for example, an  
15 infected CD4<sup>+</sup> cell or an infected monocyte or macrophage. Without limiting the present invention in any way, the ability of HIV-1 to infect and efficiently replicate in macrophages is thought to be essential in AIDS pathogenesis. In fact, it has been suggested that macrophage-tropic HIV isolates may be necessary and sufficient for the development of AIDS. Accordingly, in a preferred embodiment the subject HIV infected  
20 cell is a HIV infected macrophage or monocyte.

According to this preferred embodiment there is provided a method of reducing, retarding or otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian macrophage, said method comprising administering to said mammal an  
25 effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of said macrophage.

In another preferred embodiment there is provided a method of reducing, retarding or otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian  
30 macrophage, said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel

- 14 -

functional activity of said monocyte.

In a related aspect, the inventors have also surprisingly determined that analogues of amiloride inhibit Vpu ion channel functional activity. This was an unexpected result due to the *prima facie* incompatible structure of the subject analogue with the Vpu ion channel. Specifically, without limiting the present invention to any one theory or mode of action, amiloride analogues are thought to inhibit HIV viron release from cells by causing the Vpu ion channels to become blocked. This blocking is effected by substituted amiloride but not by unsubstituted amiloride. Unsubstituted amiloride is a pyrazinoylguanidine bearing amino groups on the 3- and 5- positions and a chloro group on the 6- position of the pyrazine ring. However, the present invention should not be understood as limited to analogues of this form of amiloride or functional equivalents thereof. The present invention encompasses analogues of any form of amiloride. For example, other isomeric forms of amiloride. Accordingly, reference to "amiloride analogue" should be understood as a reference to any amiloride molecule which exhibits an addition, deletion or substitution, such as an addition, deletion or substitution of an atom or molecule or changing of the charge of an atom or molecule, at any position but more particularly at any one or more of the 6 positions of the pyrazine ring. Preferably, said amiloride analogue is an amiloride molecule exhibiting a substitution of the amino group at the 5- position of the pyrazine ring.

Accordingly, in a preferred embodiment the present invention provides a method of reducing, retarding or otherwise inhibiting HIV replication, which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of an amiloride analogue, or functional equivalent thereof, for a time and under conditions sufficient to inhibit Vpu ion channel functional activity.

Preferably, said amiloride analogue comprises a substitution of the amino group at the 5- position of the pyrazine ring or functional equivalent thereof. Even more preferably, said Vpu ion channel functional activity is Vpu ion channel mediation of HIV replication.

- 15 -

Still more preferably, said amiloride analogue is 5-(N,N-Hexamethylene)-Amiloride (referred to herein as "HMA") or 5-(N,N-Dimethyl)-Amiloride (referred to herein as "DMA").

5 According to this preferred embodiment there is provided a method of reducing, retarding or otherwise inhibiting HIV replication, which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of HMA or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel mediation of HIV replication.

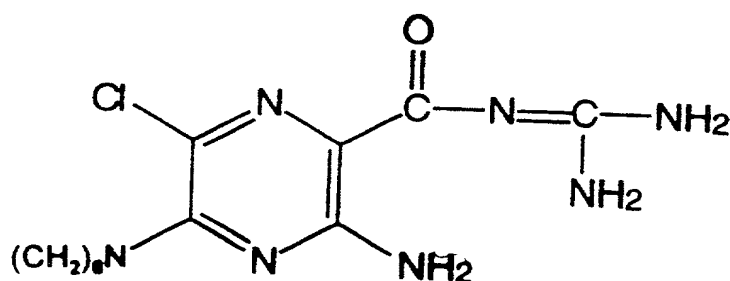
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In another preferred embodiment there is provided a method of reducing, retarding or otherwise inhibiting HIV replication which HIV has infected a mammalian host cell, said method comprising contacting said host cell with an effective amount of DMA or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel

15 mediation of HIV replication.

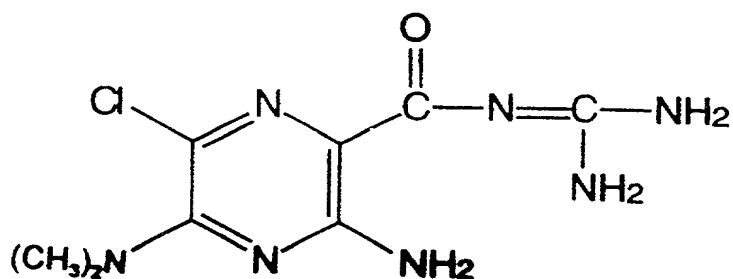
Most preferably said amiloride analogues comprise the structure:

20



HMA

25



30

DMA



"Functional equivalents" of amiloride analogues and any other proteinaceous or non-proteinaceous agents which exhibit functional activity equivalent to the amiloride analogues (to the extent that Vpu ion channel functional activity is inhibited or otherwise down-regulated as hereinbefore defined), include functionally active derivatives, fragments, parts, portions and chemical equivalents from natural, synthetic or recombinant sources, including fusion proteins. Chemical equivalents may not necessarily be derived from the subject agent but may share certain conformational similarity. Alternatively, chemical equivalents may be specifically designed to mimic certain physiochemical properties of the agent. Chemical equivalents may be chemically synthesised or may be detected following, for example, natural product screening. Functional equivalents may also possess antagonistic or agonistic properties and the use of such molecules are contemplated by the present invention.

Where the agent or functional equivalent is a proteinaceous molecule, the present invention should be understood to extend to functional derivatives of said proteinaceous molecule. Derivatives include fragments, parts, portions, mutants, and mimetics from natural, synthetic or recombinant sources including fusion proteins. Derivatives may be derived from insertion, deletion or substitution of amino acids. Amino acid insertional derivatives include amino and/or carboxylic terminal fusions as well as intrasequence insertions of single or multiple amino acids. Insertional amino acid sequence variants are those in which one or more amino acid residues are introduced into a predetermined site in the protein although random insertion is also possible with suitable screening of the resulting product. Deletional variants are characterized by the removal of one or more amino acids from the sequence. Substitutional amino acid variants are those in which at least one residue in the sequence has been removed and a different residue inserted in its place. An example of substitutional amino acid variants are conservative amino acid substitutions. Conservative amino acid substitutions typically include substitutions within the following groups: glycine and alanine; valine, isoleucine and leucine; aspartic acid and glutamic acid; asparagine and glutamine; serine and threonine; lysine and arginine; and phenylalanine and tyrosine. Additions to amino acid sequences including fusions with other peptides, polypeptides or proteins.

Homologs of the protein contemplated herein include, but are not limited to, proteins derived from different species.

The derivatives include fragments having particular epitopes of parts of the entire protein fused to peptides, polypeptides or other proteinaceous or non-proteinaceous molecules. For example, a protein (or a non-proteinaceous molecule) or derivative thereof may be fused to a molecule to facilitate its entry into a cell.

Reference to "derivatives" should also be understood to include reference to analogues.

- 10 Analogues contemplated herein include, but are not limited to, modification to side chains, incorporating of unnatural amino acids and/or their derivatives during peptide, polypeptide or protein synthesis and the use of crosslinkers and other methods which impose conformational constraints on the proteinaceous molecules or their analogues.
- 15 Examples of side chain modifications contemplated by the present invention include modifications of amino groups such as by reductive alkylation by reaction with an aldehyde followed by reduction with  $\text{NaBH}_4$ ; amidination with methylacetimidate; acylation with acetic anhydride; carbamoylation of amino groups with cyanate; trinitrobenzylation of amino groups with 2, 4, 6-trinitrobenzene sulphonic acid (TNBS);
- 20 acylation of amino groups with succinic anhydride and tetrahydrophthalic anhydride; and pyridoxylation of lysine with pyridoxal-5-phosphate followed by reduction with  $\text{NaBH}_4$ .

The guanidine group of arginine residues may be modified by the formation of heterocyclic condensation products with reagents such as 2,3-butanedione, phenylglyoxal and glyoxal.

The carboxyl group may be modified by carbodiimide activation *via* O-acylisourea formation followed by subsequent derivitisation, for example, to a corresponding amide.

- 30 Sulphydryl groups may be modified by methods such as carboxymethylation with iodoacetic acid or iodoacetamide; performic acid oxidation to cysteic acid; formation of a

mixed disulphides with other thiol compounds; reaction with maleimide, maleic anhydride or other substituted maleimide; formation of mercurial derivatives using 4-chloromercuribenzoate, 4-chloromercuriphenylsulphonic acid, phenylmercury chloride, 2-chloromercuri-4-nitrophenol and other mercurials; carbamoylation with cyanate at alkaline 5 pH.

Tryptophan residues may be modified by, for example, oxidation with N-bromosuccinimide or alkylation of the indole ring with 2-hydroxy-5-nitrobenzyl bromide or sulphenyl halides. Tyrosine residues on the other hand, may be altered by nitration 10 with tetranitromethane to form a 3-nitrotyrosine derivative.

Modification of the imidazole ring of a histidine residue may be accomplished by alkylation with iodoacetic acid derivatives or N-carboethoxylation with diethylpyrocarbonate. 15

Examples of incorporating unnatural amino acids and derivatives during protein synthesis include, but are not limited to, use of norleucine, 4-amino butyric acid, 4-amino-3-hydroxy-5-phenylpentanoic acid, 6-aminohexanoic acid, t-butylglycine, norvaline, phenylglycine, ornithine, sarcosine, 4-amino-3-hydroxy-6-methylheptanoic acid, 2-thienyl 20 alanine and/or D-isomers of amino acids. A list of unnatural amino acid contemplated herein is shown in Table 1.

TABLE 1

Non-conventional amino acid	Code	Non-conventional amino acid	Code
5			
$\alpha$ -aminobutyric acid	Abu	L-N-methylalanine	Nmala
$\alpha$ -amino- $\alpha$ -methylbutyrate	Mgab	L-N-methylarginine	Nmarg
aminocyclopropane- carboxylate	Cpro	L-N-methylasparagine	Nmasn
		L-N-methylaspartic acid	Nmasp
10 $\alpha$ -aminoisobutyric acid	Aib	L-N-methylcysteine	Nmcys
aminonorbornyl- carboxylate	Norb	L-N-methylglutamine	Nmgln
		L-N-methylglutamic acid	Nmglu
cyclohexylalanine		Chexa L-N-methylhistidine	Nmhis
cyclopentylalanine	Cpen	L-N-methylisoleucine	Nmile
15 D-alanine	Dal	L-N-methylleucine	Nmleu
D-arginine	Darg	L-N-methyllysine	Nmlys
D-aspartic acid	Dasp	L-N-methylmethionine	Nmmet
D-cysteine	Dcys	L-N-methylnorleucine	Nmnle
D-glutamine	Dgln	L-N-methylnorvaline	Nmnva
20 D-glutamic acid	Dglu	L-N-methylornithine	Nmorn
D-histidine	Dhis	L-N-methylphenylalanine	Nmphe
D-isoleucine	Dile	L-N-methylproline	Nmpro
D-leucine	Dleu	L-N-methylserine	Nmser
D-lysine	Dlys	L-N-methylthreonine	Nmthr
25 D-methionine	Dmet	L-N-methyltryptophan	Nmtrp
D-ornithine	Dorn	L-N-methyltyrosine	Nmtyr
D-phenylalanine	Dphe	L-N-methylvaline	Nmval
D-proline	Dpro	L-N-methylethylglycine	Nmetg
D-serine	Dser	L-N-methyl-t-butylglycine	Nmtbug
30 D-threonine	Dthr	L-norleucine	Nle
D-tryptophan	Dtrp	L-norvaline	Nva

	D-tyrosine	Dtyr	$\alpha$ -methyl-aminoisobutyrate	Maib
	D-valine	Dval	$\alpha$ -methyl- $\gamma$ -aminobutyrate	Mgab
	D- $\alpha$ -methylalanine	Dmala	$\alpha$ -methylcyclohexylalanine	Mchexa
	D- $\alpha$ -methylarginine	Dmarg	$\alpha$ -methylcyclopentylalanine	Mcpen
5	D- $\alpha$ -methylasparagine	Dmasn	$\alpha$ -methyl- $\alpha$ -naphthylalanine	Manap
	D- $\alpha$ -methylaspartate	Dmasp	$\alpha$ -methylpenicillamine	Mpen
	D- $\alpha$ -methylcysteine	Dmcys	N-(4-aminobutyl)glycine	Nglu
	D- $\alpha$ -methylglutamine	Dmgln	N-(2-aminoethyl)glycine	Naeg
	D- $\alpha$ -methylhistidine	Dmhis	N-(3-aminopropyl)glycine	Norn
10	D- $\alpha$ -methylisoleucine	Dmile	N-amino- $\alpha$ -methylbutyrate	Nmaabu
	D- $\alpha$ -methylleucine	Dmleu	$\alpha$ -naphthylalanine	Anap
	D- $\alpha$ -methyllysine	Dmlys	N-benzylglycine	Nphe
	D- $\alpha$ -methylmethionine	Dmmet	N-(2-carbamylethyl)glycine	Ngln
	D- $\alpha$ -methylornithine	Dmorn	N-(carbamylmethyl)glycine	Nasn
15	D- $\alpha$ -methylphenylalanine	Dmphe	N-(2-carboxyethyl)glycine	Nglu
	D- $\alpha$ -methylproline	Dmpro	N-(carboxymethyl)glycine	Nasp
	D- $\alpha$ -methylserine	Dmser	N-cyclobutylglycine	Ncbut
	D- $\alpha$ -methylthreonine	Dmthr	N-cycloheptylglycine	Nchep
	D- $\alpha$ -methyltryptophan	Dmtrp	N-cyclohexylglycine	Nchex
20	D- $\alpha$ -methyltyrosine	Dmty	N-cyclodecylglycine	Ncdec
	D- $\alpha$ -methylvaline	Dmval	N-cylcododecylglycine	Ncdod
	D-N-methylalanine	Dnmala	N-cyclooctylglycine	Ncoct
	D-N-methylarginine	Dnmarg	N-cyclopropylglycine	Ncpro
	D-N-methylasparagine	Dnmasn	N-cycloundecylglycine	Ncund
25	D-N-methylaspartate	Dnmasp	N-(2,2-diphenylethyl)glycine	Nbhm
	D-N-methylcysteine	Dnmcys	N-(3,3-diphenylpropyl)glycine	Nbhe
	D-N-methylglutamine	Dnmgln	N-(3-guanidinopropyl)glycine	Narg
	D-N-methylglutamate	Dnmglu	N-(1-hydroxyethyl)glycine	Nthr
	D-N-methylhistidine	Dnmhis	N-(hydroxyethyl)glycine	Nser
30	D-N-methylisoleucine	Dnmile	N-(imidazolylethyl)glycine	Nhis
	D-N-methylleucine	Dnmleu	N-(3-indolylethyl)glycine	Nhtro

	D-N-methyllysine	Dnmlys	N-methyl- $\gamma$ -aminobutyrate	Nmgabu
	N-methylcyclohexylalanine	Nmchexa	D-N-methylmethionine	Dnmmt
	D-N-methylornithine	Dnmorn	N-methylcyclopentylalanine	Nmcpn
	N-methylglycine	Nala	D-N-methylphenylalanine	Dnmphe
5	N-methylaminoisobutyrate	Nmaib	D-N-methylproline	Dnmpro
	N-(1-methylpropyl)glycine	Nile	D-N-methylserine	Dnmser
	N-(2-methylpropyl)glycine	Nleu	D-N-methylthreonine	Dnmthr
	D-N-methyltryptophan	Dnmtrp	N-(1-methylethyl)glycine	Nval
	D-N-methyltyrosine	Dnmtyr	N-methyl- $\alpha$ -naphthylalanine	Nmanap
10	D-N-methylvaline	Dnmval	N-methylpenicillamine	Nmpen
	$\gamma$ -aminobutyric acid	Gabu	N-( <i>p</i> -hydroxyphenyl)glycine	Nhtyr
	L- <i>t</i> -butylglycine	Tbug	N-(thiomethyl)glycine	Ncys
	L-ethylglycine	Etg	penicillamine	Pen
	L-homophenylalanine	Hphe	L- $\alpha$ -methylalanine	Mala
15	L- $\alpha$ -methylarginine	Marg	L- $\alpha$ -methylassparagine	Masn
	L- $\alpha$ -methylasspartate	Masp	L- $\alpha$ -methyl- <i>t</i> -butylglycine	Mtbug
	L- $\alpha$ -methylcysteine	Mcys	L-methylethylglycine	Metg
	L- $\alpha$ -methylglutamine	Mgln	L- $\alpha$ -methylglutamate	Mglu
	L- $\alpha$ -methylhistidine	Mhis	L- $\alpha$ -methylhomophenylalanine	Mhphe
20	L- $\alpha$ -methylisoleucine	Mile	N-(2-methylthioethyl)glycine	Nmet
	L- $\alpha$ -methyllleucine	Mleu	L- $\alpha$ -methyllysine	Mlys
	L- $\alpha$ -methylmethionine	Mmet	L- $\alpha$ -methylnorleucine	Mnle
	L- $\alpha$ -methylnorvaline	Mnva	L- $\alpha$ -methylornithine	Morn
	L- $\alpha$ -methylphenylalanine	Mphe	L- $\alpha$ -methylproline	Mpro
25	L- $\alpha$ -methylserine	Mser	L- $\alpha$ -methylthreonine	Mthr
	L- $\alpha$ -methyltryptophan	Mtrp	L- $\alpha$ -methyltyrosine	Mtyr
	L- $\alpha$ -methylvaline	Mval	L-N-methylhomophenylalanine	Nmhph
	N-(N-(2,2-diphenylethyl)	Nnbhm	N-(N-(3,3-diphenylpropyl)	Nnbhe
	carbamylmethyl)glycine		carbamylmethyl)glycine	
30	1-carboxy-1-(2,2-diphenyl-Nmbc			
	ethylamino)cyclopropane			

Crosslinkers can be used, for example, to stabilise 3D conformations, using homo-bifunctional crosslinkers such as the bifunctional imido esters having  $(CH_2)_n$  spacer groups with  $n=1$  to  $n=6$ , glutaraldehyde, N-hydroxysuccinimide esters and hetero-  
5 bifunctional reagents which usually contain an amino-reactive moiety such as N-hydroxysuccinimide and another group specific-reactive moiety.

The subject of the viral inhibition is generally a mammal such as but not limited to human, primate, livestock animal (e.g. sheep, cow, horse, donkey, pig), companion  
10 animal (e.g. dog, cat), laboratory test animal (e.g. mouse, rabbit, rat, guinea pig, hamster), captive wild animal (e.g. fox, deer). Preferably, the subject is a human or primate. Most preferably, the subject is a human.

The method of the present invention is useful in the treatment and prophylaxis of HIV  
15 infection and AIDS. For example, the down-regulation of Vpu ion channel functional activity may be effected in subjects known to be infected with HIV in order to prevent replication of HIV thereby preventing the onset of AIDS. Alternatively, the method of the present invention may be used to reduce serum viral load or to alleviate AIDS symptoms.

20 The method of the present invention may be particularly useful either early in HIV infection to prevent the establishment of a viral reservoir in cell types such as monocytes and macrophages or as a prophylactic treatment to be applied immediately prior to or for a period after exposure to a possible source of HIV infection.

25 Accordingly, in another aspect there is provided a method for the treatment and/or prophylaxis of HIV infection or AIDS in a mammal said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of an HIV  
30 infected mammalian host cell, wherein said Vpu functional activity down-regulation reduces, retards or otherwise inhibits the functional activity of said HIV.

More particularly, the present invention provides a method for the treatment and/or prophylaxis of HIV infection or AIDS in a mammal said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of an HIV  
5 infected mammalian host cell, wherein said Vpu functional activity down-regulation reduces, retards or otherwise inhibits HIV replication.

Reference to "an effective amount" means an amount necessary to at least partly attain the desired response.

10

Reference herein to "treatment" and "prophylaxis" is to be considered in its broadest context. The term "treatment" does not necessarily imply that a mammal is treated until total recovery. Similarly, "prophylaxis" does not necessarily mean that the subject will not eventually contract a disease condition. Accordingly, treatment and prophylaxis  
15 include amelioration of the symptoms of a particular condition or preventing or otherwise reducing the risk of developing a particular condition. The term "prophylaxis" may be considered as reducing the severity of onset of a particular condition. "Treatment" may also reduce the severity of an existing condition or the frequency of acute attacks.

20 Preferably said agent is an amiloride analogue or functional equivalent thereof. Even more preferably, said amiloride analogue is HMA or DMA.

In accordance with this method, more than one type of agent may be administered or the agent may be co-administered with another molecule such as a known anti-viral  
25 compound or molecule. By "co-administered" is meant simultaneous administration in the same formulation or in two different formulations via the same or different routes or sequential administration by the same or different routes. By "sequential" administration is meant a time difference of from seconds, minutes, hours or days between the administration of the two types of an amiloride analogue or the amiloride analogue and  
30 the known anti-viral compound or molecule. The subject agent and known anti-viral compound or molecule may be administered in any order.



Routes of administration include but are not limited to intravenously, intraperitoneally, subcutaneously, intracranially, intradermally, intramuscularly, intraocularly, intrathecally, intracerebrally, intranasally, by infusion, orally, rectally, *via* iv drip, patch and implant. Intravenous routes are particularly preferred.

5

The present invention further extends to the use of the subject agents in the manufacture of a medicament for the therapeutic or prophylactic treatment of HIV infection or AIDS in a mammal wherein said agent reduces, retards or otherwise inhibits Vpu ion channel functional activity of an HIV infected cell.

10

Preferably said functional activity is mediation of HIV replication.

Most preferably said agent is an amiloride analogue or functional equivalent thereof and still more preferably HMA or DMA or functional equivalent thereof.

15

As detailed previously, the inventors have surprisingly determined that although amiloride has no effect on Vpu ion channel functional activity, amiloride analogues are able to block functional activity.

20 Accordingly, another aspect of the present invention provides a method of reducing, retarding or otherwise inhibiting membrane ion channel functional activity in a subject said method comprising administering to said subject an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit membrane ion channel functional activity.

25

More particularly, the present invention provides a method of reducing, retarding or otherwise inhibiting Vpu ion channel functional activity in a mammal said method comprising administering to said mammal an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu

30 ion channel functional activity.

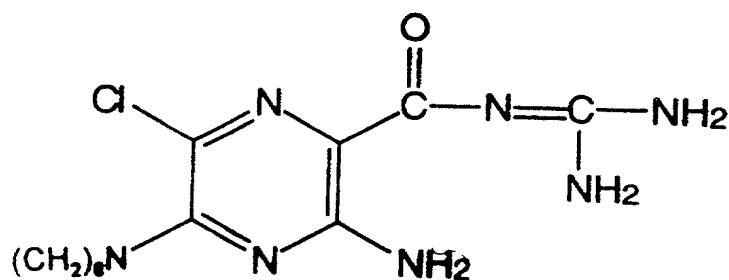
Still more preferably, the present invention provides a method of reducing, retarding or otherwise inhibiting Vpu ion channel mediation of HIV replication in a mammal said method comprising administering to said mammal an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to  
5 inhibit Vpu ion channel functional activity.

Preferably, said amiloride analogue comprises a substitution of the amino group of the 5-position of the pyrazine ring or functional equivalent thereof.

10 Even more preferably, said amiloride analogue is HMA or DMA.

Most preferably, said amiloride analogues comprise the structure:

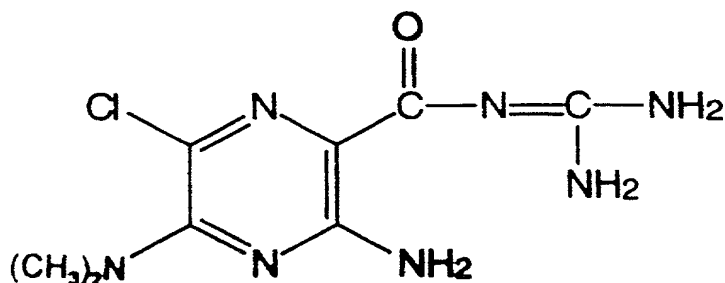
15



20

HMA

25



DMA

30

Yet another aspect of the present invention provides an agent useful for reducing, retarding or otherwise inhibiting Vpu ion channel functional activity as hereinbefore defined.

- 5 Preferably said functional activity is mediation of HIV replication.

Most preferably said agent is an amiloride analogue or functional equivalent thereof and even more particularly said agent is HMA or DMA or functional equivalent thereof.

- 10 Still another aspect of the present invention provides a composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity comprising an agent as hereinbefore defined and one or more pharmaceutically acceptable carriers and/or diluents. The composition may also comprise two different types of agents or an agent and a known anti-viral compound or molecule.

15

Preferably said inhibition of ion channel functional activity is inhibition of Vpu ion channel mediation of HIV replication.

- Compositions suitable for injectable use include sterile aqueous solutions (where water  
20 soluble) and sterile powders for the extemporaneous preparation of sterile injectable solutions. They must be stable under the conditions of manufacture and storage and must be preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol and liquid polyethylene  
25 glycol, and the like), suitable mixtures thereof and vegetable oils. The preventions of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimerosal and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought  
30 about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

- 27 -

5 Sterile injectable solutions are prepared by incorporating the active compounds in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by, for example, filter sterilization or sterilization by other appropriate means. Dispersions are also contemplated and these may be prepared by incorporating the various sterilized active ingredients into a sterile vehicle which contains the basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, a preferred method of preparation includes vacuum drying and the freeze-drying technique which yield a powder of the active ingredient plus any additional  
10 desired ingredient from a previously sterile-filtered solution.

When the active ingredients are suitably protected, they may be orally administered, for example, with an inert diluent or with an assimilable edible carrier, or it may be enclosed in hard or soft shell gelatin capsule, or it may be compressed into tablets. For oral  
15 therapeutic administration, the active compound may be incorporated with excipients and used in the form of ingestible tablets, buccal tablets, troches, capsules, elixirs, suspensions, syrups, wafers, and the like. Such compositions and preparations should contain at least 1% by weight of active compound. The percentage of the compositions and preparations may, of course, be varied and may conveniently be between about 5 to  
20 about 80% of the weight of the unit. The amount of active compound in such therapeutically useful compositions in such that a suitable dosage will be obtained. Preferred compositions or preparations according to the present invention are prepared so that an oral dosage unit form contains between about 0.1mg and 2000 mg of active compound.

25 The tablets, troches, pills, capsules and the like may also contain the components as listed hereafter: A binder such as gum, acacia, corn starch or gelatin; excipients such as dicalcium phosphate; a disintegrating agent such as corn starch, potato starch, alginic acid and the like; a lubricant such as magnesium stearate; and a sweetening agent such a  
30 sucrose, lactose or saccharin may be added or a flavouring agent such as peppermint, oil of wintergreen, or cherry flavouring. When the dosage unit form is a capsule, it may

- 28 -

contain, in addition to materials of the above type, a liquid carrier. Various other materials may be present as coatings or to otherwise modify the physical form of the dosage unit. For instance, tablets, pills, or capsules may be coated with shellac, sugar or both. A syrup or elixir may contain the active compound, sucrose as a sweetening agent, methyl and propylparabens as preservatives, a dye and flavouring such as cherry or orange flavour. Any material used in preparing any dosage unit form should be pharmaceutically pure and substantially non-toxic in the amounts employed. In addition, the active compound(s) may be incorporated into sustained-release preparations and formulations.

10

The present invention also extends to forms suitable for topical application such as creams, lotions and gels. In such forms, the anti-clotting peptides may need to be modified to permit penetration of the surface barrier.

- 15 Pharmaceutically acceptable carriers and/or diluents include any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents and the like. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any conventional media or agent is incompatible with the active ingredient, use thereof in the therapeutic compositions is contemplated. Supplementary active ingredients can also be incorporated into the compositions.

It is especially advantageous to formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the mammalian subjects to be treated; each unit containing a predetermined quantity of active material calculated to produce the desired therapeutic effect in association with the required pharmaceutical carrier. The specification for the novel dosage unit forms of the invention are dictated by and directly dependent on (a) the unique characteristics of the active material and the particular therapeutic effect to be achieved and (b) the limitations inherent in the art of compounding.

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Effective amounts contemplated by the present invention will vary depending on the severity of the pain and the health and age of the recipient. In general terms, effective amounts may vary from 0.01 ng/kg body weight to about 100 mg/kg body weight.

Alternative amounts include for about 0.1 ng/kg body weight about 100 mg/kg body weight or from 1.0 ng/kg body weight to about 80 mg/kg body weight.

Further features of the present invention are more fully described in the following Examples. It is to be understood, however, that the detailed description is included solely for the purpose of exemplifying the present invention. It should not be understood in any way as a restriction on the broad description of the invention as set out above.

## EXAMPLE 1

## Construction of recombinant plasmids p2GEXVpu and pPLVpu

The open reading frame encoding Vpu (Fig 1a) was amplified by PCR from a cDNA  
5 clone of an Nde 1 fragment of the HIV-1 genome (isolate HXB2, McFarlane Burnet  
Centre, Melbourne, Australia). Native *Pfu* DNA polymerase (Stratagene; 0.035 U/ $\mu$ l)  
was chosen to catalyse the PCR reaction to minimise possible PCR introduced errors by  
virtue of the enzyme's proofreading activity. The 5', sense, primer  
AGTAGGATCCATGCAACCTATACC (<400>2) introduces a BamH1 site  
10 (underlined) for cloning in-frame with the 3' end of the GST gene in p2GEX (41). This  
primer also repairs the start codon (bold T replaces a C) of the *vpu* gene which is a  
threonine codon in the HXB2 isolate. The 3', antisense, primer  
TCTGGAATTCTACAGATCAT CAAC (<400>3) introduces an EcoR1 site  
(underlined) to the other end of the PCR product to facilitate cloning. After 30 cycles of  
15 94°C for 45 sec, 55°C for 1 min and 72°C for 1 min in 0.5 ml thin-walled eppendorf  
tubes in a Perkin-Elmer thermocycler, the 268bp fragment was purified, digested with  
BamH1 and EcoR1 and ligated to p2GEX prepared by digestion with the same two  
enzymes. The resultant recombinant plasmid is illustrated in Fig 1b. The entireVpu  
open reading frame and the BamH1 and EcoR1 ligation sites were sequenced by cycle  
20 sequencing, using the Applied Biosystems dye-terminator kit, to confirm the DNA  
sequence.

To prepare the Vpu open reading frame for insertion into the pPL451 expression  
plasmid, p2GEXVpu was first digested with BamH1 and the 5' base overhang was filled  
25 in the Klenow DNA polymerase in the presence of dNTPs. The Vpu-encoding fragment  
was then liberated by digestion with EcoR1, purified from an agarose gel and ligated into  
pPL451 which had been digested with HpaI and EcoR1. Western blots subsequently  
confirmed that the pPLVpu construct (Fig 1c) expressed Vpu after induction of cultures  
at 42°C to inactivate the cI857 repressor of the PR and PL promoters.

## EXAMPLE 2

### Raising polyclonal antibodies for immuno-identification of Vpu

A peptide CALVEMGVEMGHHPWDVDDL (<400>4) corresponding to the C-terminal 20 amino acid residues of Vpu was synthesised in the Biomolecular Resource Facility (ANU, Australia) using an Applied Biosystems model 477A machine. A multiple antigenic peptide (MAP) was prepared (Lu *et al*, 1991) by coupling the peptide to a polylysine core via the N-terminal cysteine residue. The MAP was used to immunise rabbits for production of polyclonal antisera recognising the C-terminus of Vpu. For immunisations 1mg of MAP peptide was dissolved in 1.25ml of MTPBS (16mM Na<sub>2</sub>HPO<sub>4</sub>, 4mM NaHPO<sub>4</sub>, 150mM NaCl pH 7.3) and emulsified with 1.25ml of Freund's complete adjuvant and injected at multiple subcutaneous sites on the rabbit's back. Booster injections used Freund's incomplete adjuvant and were spaced at least 4 weeks apart with serum being sampled 10-14 days after injections.

15

## EXAMPLE 3

### Techniques involving the antibodies

Peptide-specific antibodies were purified from rabbit sera using an Immunopure™ Ag/Ab Immobilisation kit from Pierce. The synthetic peptide was cross-linked via its N-terminal cysteine to the matrix of a 5ml Sulfo Link™ column according to the kit's instructions, 2.5ml of Vpu immunoreactive serum was added to 20ml of Tris buffer (10mM pH 7.4) and passed through the peptide column three times to maximise exposure of the antibodies to the peptide. The column was washed with 20ml of 10mM Tris pH 7.4 followed by 20ml of the same buffer supplemented with 500mM NaCl. The bound antibodies were eluted in 5ml of 100mM glycine/150mM NaCl, pH 2.5 and eluents were immediately neutralised by addition of 250μl of 1M Tris pH 9.0 and dialysed overnight against MTPBS.

30 An anti-Vpu immunoaffinity column was constructed by covalently cross-linking 200μg of purified antibody to 100μl of protein A agarose beads (Schleicher and Schuell) using



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the bifunctional cross-linking reagent dimethylpimelimidate as described previously (Harlow and Lane, 1988).

- Immunoprecipitation of Vpu was performed by incubation of samples in the presence of approximately 5-fold excess of purified antibody (room temperature for 1 hr) followed by addition of excess protein-A agarose, incubation for 30 min, and centrifugation to pellet the Vpu-antibody complexes. The supernatant, which was subsequently used as a control in the electrophysiological bilayer experiments, was tested by western blotting to confirm that Vpu had been completely removed. Protein samples were electrophoresed on homogeneous 18% SDS polyacrylamide gels using a minigel apparatus and pre-poured gels (Novex). Samples were treated with SDS (3.2% final) and mercaptoethanol (0.8% final) at 60°C for 5 min before loading onto gels. Protein bands were visualised either with Coomassie brilliant blue R250 or by silver staining.
- For western blotting, proteins were transferred from acrylamide gels to PVDF membranes using a semi-dry transfer apparatus (Pharmacia LKB). Vpu was detected after consecutive reactions of the blots with polyclonal antiserum or purified antibodies, goat anti-rabbit alkaline phosphatase conjugate and Western Blue™ stabilised substrate (Promega).

20

#### EXAMPLE 4

##### PURIFICATION OF RECOMBINANT VPU FROM *E. COLI*

- Cultures of *E. coli* strain XL1-blue cells containing p2GEXVpu were grown at 30°C with vigorous aeration in LB medium supplemented with glucose (6g/L) and ampicillin (50mg/L) to a density of approximately 250 Klett units, at which time IPTG was added to a final concentration of 0.01mM and growth was continued for a further 4hr. The final culture density was approximately 280 Klett units. Since early experiments revealed that the majority of expressed GST-Vpu fusion protein was associated with both the cell debris and membrane fractions, the method of Varadhachary and Maloney (Varadhachary and Maloney, 1990) was adopted to isolate osmotically disrupted cell ghosts (combining both cell debris

and membrane fractions) for the initial purification steps. Cells were harvested, washed, weighed and resuspended to 10ml/g wet weight in MTPBS containing DTT (1mM) and  $MgCl_2$  (10mM). Lysozyme (0.3 mg/ml; chicken egg white; Sigma) was added and incubated on ice for 30 min with gentle agitation followed by 5 min at 37°C. The osmotically sensitised cells were pelleted at 12,000g and resuspended to the original volume in water to burst the cells. The suspension was then made up to 1xMTPBS/DTT using a 10x buffer stock and the ghosts were isolated by centrifugation and resuspended in MTPBS/DTT to which was then sequentially added glycerol (to 20% wt/vol) and CHAPS (to 2% wt/vol) to give a final volume of one quarter the original volume. This mixture was stirred on ice for 1 hr and then centrifuged at 400,000g for 1hr to remove insoluble material. The GST-Vpu fusion protein was purified from the detergent extract by affinity chromatography on a glutathione agarose resin (Sigma). The resin was thoroughly washed in 50mM Tris pH 7.5 containing glycerol (5%), DTT (1mM), and CHAPS (0.5%) (Buffer A) and then the Vpu portion of the fusion protein was liberated and eluted from the resin-bound GST by treatment of a 50% (v/v) suspension of the beads with human thrombin (100U/ml; 37°C for 1hr). PMSF (0.5mM) was added to the eluant to eliminate any remaining thrombin activity. This Vpu fraction was further purified on a column of MA7Q anion exchange resin attached to a BioRad HPLC and eluted with a linear NaCl gradient (0-2M) in buffer A.

The Vpu was purified to homogeneity - as determined on silver stained gels - on an immunoaffinity column as follows: HPLC fractions containing Vpu were desalted on a NAP 25 column (Pharmacia) into buffer A and then mixed with the antibody-agarose beads for 1hr at room temperature. The beads were washed thoroughly and Vpu was eluted by increasing the salt concentration to 2M. Protein was quantitated using the BioRad dye-binding assay.

### EXAMPLE 5

#### RECONSTITUTION OF VPU IN PHOSPHOLIPID VESICLES

Proteoliposomes containing Vpu were prepared by the detergent dilution method (New, 1990). A mixture of lipids (PE:PC:PS; 5:3:2; 1mg total lipid) dissolved in chloroform was

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dried under a stream of nitrogen gas and resuspended in 0.1 ml of potassium phosphate buffer (50mM pH 7.4) containing DTT (1mM). A 25 $\mu$ l aliquot containing purified Vpu was added, followed by octylglucoside to a final concentration of 1.25% (wt/vol). This mixture was subject to three rounds of freezing in liquid nitrogen, thawing and sonication in a bath-  
5 type sonicator (20-30 sec) and was then rapidly diluted into 200 volumes of the potassium phosphate buffer. Proteoliposomes were collected by centrifugation at 400,000g for 1hr and resuspended in approximately 150 $\mu$ l of phosphate buffer.

### EXAMPLE 6

10

#### ASSAYING ION CHANNEL ACTIVITY

Purified Vpu was tested for its ability to induce channel activity in planar lipid bilayers using standard techniques as described elsewhere (Miller, 1986; and Piller *et al*, 1996). The solutions in the CIS and TRANS chambers were separated by a Delrin<sup>TM</sup> plastic wall  
15 containing a small circular hole of approximately 100 $\mu$ m diameter across which a lipid bilayer was painted so as to form a high resistance electrical seal. Bilayers were painted from a mixture (8:2) of palmitoyl-oleoyl-phosphatidyl-ethanolamine and palmitoyl-oleoyl-phosphatidyl-choline (Avanti Polar Lipids, Alabaster, Alabama) in n-decane. The solutions in the two chambers contained MES buffer (10mM, pH 6.0) to which various NaCl or KCl  
20 concentrations were added. Currents were recorded with an Axopatch<sup>TM</sup> 200 amplifier. The electrical potential between the two chambers could be manipulated between  $\pm$ 200mV (TRANS relative to grounded CIS). Aliquots containing Vpu were added to the CIS chamber either as a detergent solution or after incorporation of the protein into phospholipid vesicles. The chamber was stirred until currents were observed.

25

### EXAMPLE 7

#### TESTING THE EFFECT OF HMA AND DMA ON HIV REPLICATION IN HUMAN MONOCYTES AND MACROPHAGES

30 Human monocytes were isolated from peripheral blood and cultured either for 24hr (one day old monocytes) or for 7 days to allow differentiation into monocyte derived macrophages

(MDM). These cells were then exposed to cell-free preparations of HIV isolates and allowed to absorb for 2hr before complete aspiration of the medium, washing once with virus-free medium and resuspension in fresh medium. The cells were exposed to 50-10 $\mu$ M HMA or DMA either 24 hr prior to infection or after infection. Subsequent HIV replication, at various times after infection, was compared in cells exposed to drugs and in cells not exposed to drugs (controls). The progression and extent of viral replication was assayed using either an HIV DNA PCR method (Fear *et al*, 1998) or an ELISA method to quantitate p24 in culture supernatants (Kelly *et al*, 1998).

10

### EXAMPLE 8

#### EXPRESSION AND PURIFICATION OF VPU IN E. COLI

The plasmid p2GEXVpu (Fig. 1) was constructed to create an in-frame gene fusion between the GST and Vpu open-reading frames. This system enabled IPTG-inducible expression of the Vpu polypeptide fused to the C-terminus of GST and allowed purification of the fusion protein by affinity chromatography on glutathione agarose.

Optimal levels of GST-Vpu expression were obtained by growing the cultures at 30°C to a cell density of approximately 250-300 Klett units and inducing with low levels of IPTG (0.01mM). To purify the GST-Vpu, a combined cellular fraction containing the cell debris and plasma membrane was prepared by lysozyme treatment of the induced cells followed by a low-speed centrifugation. Approximately 50% of the GST-Vpu protein could be solubilised from this fraction using the zwitterionic detergent CHAPS. Affinity chromatography using glutathione-agarose beads was used to enrich the fusion protein and thrombin was used to cleave the fusion protein at the high affinity thrombin site between the fusion partners, liberating Vpu (Fig. 2A). In fractions eluted from the anion exchange column Vpu was the major protein visible on silver stained gels (Fig. 2B, lane 1). Finally, Vpu was purified to apparent homogeneity on an immunoaffinity column (Fig. 2B, lane 2). The N-terminal amino acid sequence of the protein band (excised from SDS-PAGE gels) corresponding to the immunodetected protein confirmed its identity as Vpu.

### EXAMPLE 9

#### VPU FORMS ION CHANNELS IN LIPID BILAYERS

To assay for ion-channel formation by Vpu, reconstitution into planar lipid bilayers was performed. When samples (containing between 7 and 70ng of protein) of purified recombinant Vpu were added to the 1ml of buffer in the CIS chamber of the bilayer apparatus, current fluctuations were detected after periods of stirring that varied from 2 to 30 min (Fig. 3). This time taken to observe channel activity approximately correlated with the amount of protein added to the chamber. No channels were detected when control buffer aliquots or control lipid vesicles were added to the CIS chamber. In those control experiments the chambers could be stirred for more than an hour without appearance of channel activity.

### EXAMPLE 10

#### PROPERTIES OF THE VPU CHANNELS

Channel activity was observed in over 40 individual experiments with Vpu samples prepared from five independent purifications. In different experiments, the amplitude of the currents varied over a large range and, again, seemed to approximately correlate with the amount of protein added. The smallest and largest channels measured had conductances of 14 pS and 280 pS, respectively. The channels were consistently smaller when lipid vesicles containing Vpu were prepared and fused to the bilayer rather than when purified protein in detergent solution was added. This may be because the former method included treatment with high concentrations of detergent and a dilution step that may have favoured the breakdown of large aggregates into monomers.

The relationship between current amplitude and voltage was linear and the reversal potential in solutions containing a ten-fold gradient of NaCl (500mM CIS; 50mM TRANS) was +30mV (Fig. 3B). A similar reversal potential was obtained when solutions contained KCl instead of NaCl. In 5 experiments with either NaCl or KCl in the solutions on either side of the membrane, the average reversal potential was  $31.0 \pm 1.2\text{mV}$  ( $\pm\text{SEM}$ ). This is more

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negative than expected for a channel selectively permeable for the cations alone. Using ion activities in the Goldman-Hodgkin-Katz equation gives a  $P_{Na}/P_{Cl}$  ratio of about 5.5 indicating that the channels are also permeable to chloride ions. An attempt was made to reduce the anion current by substituting phosphate for chloride ions. When a Na-phosphate gradient  
5 (150mM  $Na^+$  & 100mM phosphate CIS; 15mM  $Na^+$  & 10mM phosphate TRANS, pH 6.8) was used instead of the Na Cl gradient, the reversal potential was  $37.1 \pm 0.2$  ( $\pm$ SEM,  $n=2$ ) again indicating a cation/anion permeability ratio of about 5. (For calculations involving the phosphate solutions, the summed activities of the mono and bivalent anions were used and it was assumed that the two species were equally permeable). The current-voltage curve now  
10 exhibited rectification that was not seen in the NaCl solutions. It can be concluded that the channels formed by Vpu are equally permeable to  $Na^+$  and  $K^+$  and are also permeable, though to a lesser extent, to chloride as well as phosphate ions.

#### EXAMPLE 11

#### 15 BIO-ASSAY FOR SCREENING POTENTIAL ION-CHANNEL BLOCKING DRUGS

As part of a search for drugs that block the Vpu ion channel, a novel bio-assay was developed to facilitate the screening process which would be prohibitively slow if performed  
20 in the bilayer assay (Ewart *et al*, 1996). This bio-assay is based on the observation that expression of Vpu in *E.coli* results in an active Vpu channel located in the plasmalemma that dissipates the transmembrane sodium gradient. As a consequence of this Vpu channel activity, metabolites whose accumulation within the cells is mediated by a sodium dependent co-transporter (for example proline or adenine) leak out of the cell faster than they can be  
25 synthesised so that the metabolites' intracellular levels become limiting for growth of the cell. Thereby, an *E.coli* cell expressing Vpu is unable to grow in minimal drop-out media lacking adenine or proline. However, in the presence of a drug that blocks the Vpu channel, the cell is once again able to re-establish its transmembrane sodium gradient - due to the action of other ion pumps in the membrane - and the leakage of metabolites is prevented  
30 enabling growth. Experiments to demonstrate that Vpu can form sodium channels in the plasma membrane of *E.coli* were performed as follows:

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To express unfused Vpu in *E. coli*, the vpu open-reading frame was cloned into the plasmid pPL451 (19) to create the recombinant plasmid pPL-Vpu (Fig. 1b). In this vector the strong  $P_L$  and  $P_R$  lambda promoters are used to drive expression of Vpu under control of the temperature sensitive cI857 repressor, such that when grown at 30°C expression is tightly repressed and can be induced by raising the temperature to between 37°C and 42°C. On agar plates, cells containing pPL-Vpu grew when incubated at 30°C and 37°C but not at 42°C, while control strains grew well at 42°C. Liquid cultures of cells containing pPL-Vpu were grown at 30°C to  $OD_{600}=0.84$  then moved to grow at 42°C for two hours (the final cell density was  $OD_{600}=0.75$ ). The plasma membrane fraction was prepared and western blotting, using an antibody that specifically binds to the C-terminus of Vpu, detected a single band at approximately 16kDa, indicating that Vpu was expressed and associated with the membranes (Fig. 2A, lane 5).

## EXAMPLE 12

### 15 CROSS-FEEDING EXPERIMENTS REVEAL THAT PROLINE LEAKS OUT OF CELLS EXPRESSING VPU

Uptake of proline by *E. coli* is well characterised and active transport of the amino acid into the cells is known to use the sodium gradient as the energy source (Yamato *et al*, 1994). To detect whether proline leakage occurs, the following cross-feeding assay was used: A lawn of an *E. coli* strain auxotrophic for proline and methionine ( $Met^- Pro^-$ ), was seeded and poured as a soft agar overlay on minimal drop-out media plates lacking proline but containing methionine. Sterile porous filter discs were inoculated with a  $Met^+ Pro^+$  strain (XL-1 blue) containing either the pPL451 control plasmid or pPL-Vpu and placed onto the soft agar. The plates were then incubated at 37°C or 30°C for two days. After that time a halo growth of the  $Met^- Pro^-$  strain was clearly visible surrounding the disc inoculated with the cells containing pPL-Vpu incubated at 37°C (Fig. 4A). This growth can only be due to the leakage of proline from the Vpu-expressing cells on the disc. No such leakage was apparent from the control strain at 37°C nor around either strain on plates grown at 30°C (Fig. 4B).

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In contrast to proline transport, the *E. coli* methionine permease is known to belong to the ABC transporter family (Rosen, 1987) and hence be energised by ATP. Identical cross-feeding experiments to those described above were set up except that the Met<sup>-</sup> Pro<sup>-</sup> strain was spread on minimal drop-out plates lacking methionine but containing proline. No growth of this strain was evident around any of the discs (Fig. 4C), indicating that methionine was not leaking out of the XL-1 blue cells even when Vpu was being expressed.

### EXAMPLE 13

#### 10 *E. COLI* CELLS EXPRESSING VPU REQUIRE ADENINE IN THE EXTERNAL MEDIUM FOR GROWTH

It was observed that, due to an uncharacterised mutation in the adenine synthesis pathway, growth of *E. coli* cells of the XL1-blue strain expressing Vpu at 37°C was dependant on the presence of adenine in the medium. This allowed the development of an even simpler bio-  
15 assay for Vpu ion-channel activity than the proline cross-feeding assay described above: A lawn of XL1-blue cells containing the pPL-Vpu plasmid is seeded onto an agarose plate lacking adenine in the medium, small aliquots of drugs to be tested for inhibition of the Vpu channel are spotted onto the agarose in discrete locations and the plates are incubated at 37°C for a suitable period of time (12-36 hours). Halos of growth around a particular drug  
20 application site indicate that the drug has inhibited expression of the Vpu ion channel activity that prevents growth in the absence of the drug.

### EXAMPLE 14

#### 25 THE BIOASSAY REVEALS 5-(N,N-HEXAMETHYLENE)-AMILORIDE AS A POTENTIAL CHANNEL BLOCKER

Using this assay, a number of amantadine derivatives were tested but found not to affect channel activity. However, when a number of amiloride derivatives were also tested, a halo of growth around the site of application of 5-(N,N-Hexamethylene)-Amiloride (HMA)  
30 identified this drug as a potential Vpu channel blocker (Fig. 5). Unsubstituted amiloride did not produce a halo of bacterial growth on these plates.



**EXAMPLE 15****PLANAR LIPID BILAYER EXPERIMENTS CONFIRM HMA AS A VPU  
CHANNEL INHIBITOR**

5 Inhibition of the Vpu ion-channel activity by HMA was confirmed in planar lipid bilayer experiments (Fig. 6), where concentrations of 50-250 $\mu$ M HMA were found to block ion flow through the channel. The parent compound, amiloride, and another derivative, 5-(N,N-Dimethyl)-Amiloride (DMA), were similarly tested in planar lipid bilayer experiments: DMA was found to inhibit channel activity, though not as potently as HMA. Amiloride  
10 itself was not active as a channel blocker at these concentrations.

**EXAMPLE 16****HMA AND DMA INHIBIT HIV-1 REPLICATION IN HUMAN MONOCYTES  
AND MACROPHAGES**

15 Subsequent tests were carried out to establish whether there was any anti-viral activity of HMA and DMA. Two tests were performed to characterise the effects of the drugs on HIV replication in human monocytes and macrophages: a) A PCR based assay was used to detect newly synthesised DNA arising from reverse transcription of the HIV genome, an early  
20 stage in virus replication; b) An ELISA method was used to quantitate production of the viral protein p24, reflecting a later stage in the replication process. Results of the PCR assay indicated that DMA at 50 $\mu$ M inhibited synthesis of HIV DNA in the cells; HMA was toxic to the cells at 50 $\mu$ M - further tests are being carried out at lower concentrations of this drug. p24 ELISA results indicated a clear inhibition of HIV virion synthesis with both DMA  
25 (50 $\mu$ M, data not shown) and also with HMA (Fig. 7), when used at non-toxic levels (10 $\mu$ M); Fig. 7A shows the effect of HMA on monocytes, Fig. 7B shows the effect of HMA on macrophages.

Those skilled in the art will appreciate that the invention described herein is susceptible to  
30 variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The invention also includes

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all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations of any two or more of said steps or features.

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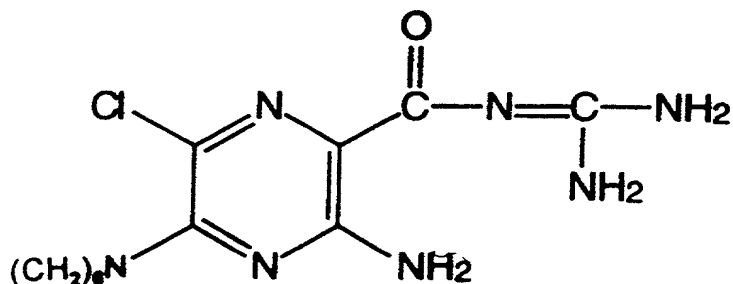
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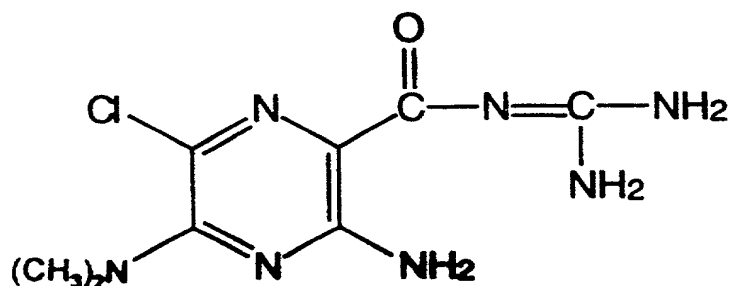
## CLAIMS:

1. A method of reducing, retarding or otherwise inhibiting the functional activity of HIV, which HIV has infected a mammalian host cell, said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate a membrane ion channel functional activity of said host cell.
2. The method according to claim 1 wherein said membrane ion channel is a Vpu ion channel.
3. The method according to claim 3 wherein said HIV functional activity is HIV replication.
4. The method according to claim 3 wherein said host cell is a macrophage.
5. The method according to claim 3 wherein said host cell is a monocyte.
6. The method according to any one of claims 1 to 5 wherein said agent is an amiloride analogue or functional equivalent thereof.
7. The method according to claim 6 wherein said amiloride analogue comprises a substitution of the amino group at the 5- position of the pyrazine ring of functional equivalent thereof.
8. The method according to claim 7 wherein said amiloride analogue is HMA or functional equivalent thereof.

9. The method according to claim 8 wherein said HMA comprise the structure:

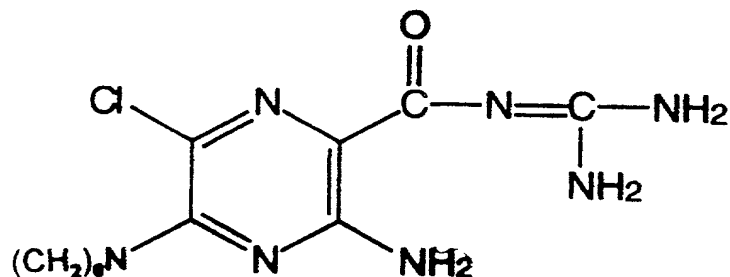


10. The method according to claim 7 wherein said amiloride analogue is DMA or functional equivalent thereof.
11. The method according to claim 10 wherein said DMA comprises the structure:

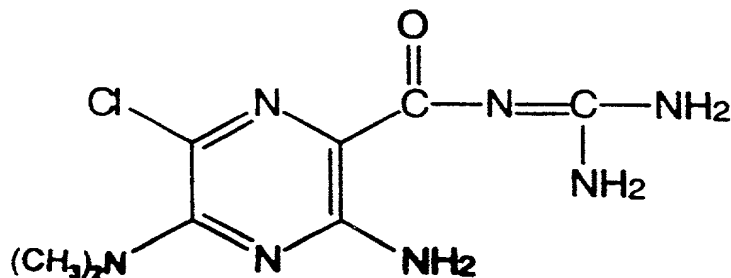


12. A method for the treatment and/or prophylaxis of HIV infection or AIDS in a mammal said method comprising administering to said mammal an effective amount of an agent for a time and under conditions sufficient to down-regulate the Vpu ion channel functional activity of an HIV infected mammalian host cell, wherein said Vpu functional activity reduces, retards or otherwise inhibits the functional activity of said HIV.
13. The method according to claim 12 wherein said HIV functional activity is HIV replication.
14. The method according to claim 13 wherein said host cell is a macrophage.

15. The method according to claim 14 wherein said host cell is a monocyte.
16. The method according to any one of claims 12 to 15 wherein said agent is an amiloride analogue or functional equivalent thereof.
17. The method according to claim 16 wherein said amiloride analogue comprises a substitution of the amino group at the 5- position of the pyrazine ring of functional equivalent thereof.
18. The method according to claim 17 wherein said amiloride analogue is HMA or functional equivalent thereof.
19. The method according to claim 18 wherein said HMA comprise the structure:



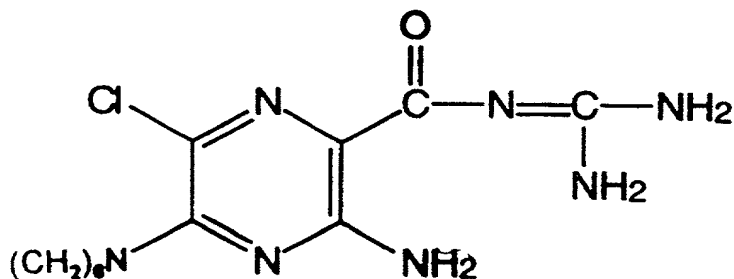
20. The method according to claim 17 wherein said amiloride analogue is DMA or functional equivalent thereof.
21. The method according to claim 20 wherein said DMA comprises the structure:





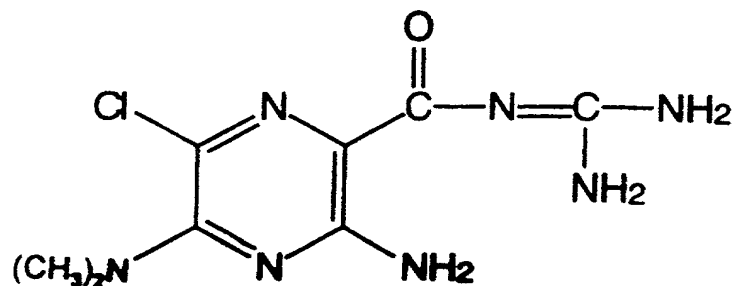
- 48 -

22. Use of an agent in the manufacture of a medicament for the therapeutic and/or prophylactic treatment of HIV infection and/or AIDS in a mammal which agent reduces, retards or otherwise inhibits the Vpu ion channel functional activity of an HIV infected cell.
23. Use according to claim 22 wherein said functional activity is the mediation of HIV replication.
24. Use according to claim 22 or 23 wherein said agent is an amiloride analogue or functional equivalent thereof.
25. Use according to claim 24 wherein said amiloride analogue comprises a substitution of the amino group at the 5- position of the pyrazine ring or functional equivalent thereof.
26. Use according to claim 25 wherein said amiloride analogue is HMA or functional equivalent thereof.
27. Use according to claim 26 wherein said HMA comprises the structure:

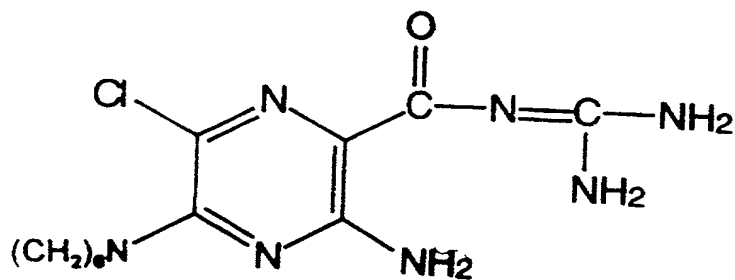


28. Use according to claim 25 wherein said amiloride analogue is DMA or functional equivalent thereof.

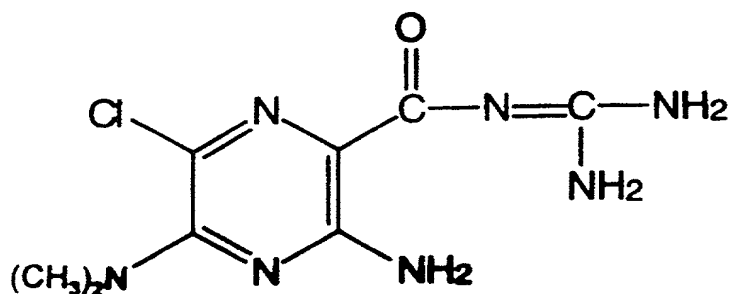
29. Use according to claim 28 wherein said DMA comprises the structure:



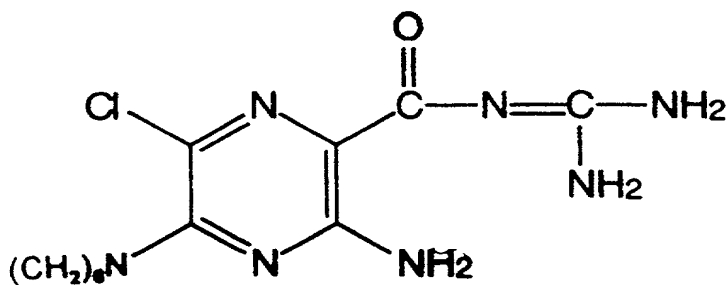
30. A method of reducing, retarding or otherwise inhibiting Vpu ion channel functional activity in a subject said method comprising administering to said subject an effective amount of an amiloride analogue or functional equivalent thereof for a time and under conditions sufficient to inhibit Vpu ion channel functional activity.
31. The method according to claim 30 wherein said Vpu ion channel functional activity is Vpu ion channel mediation of HIV replication.
32. The method according to any one of claims 30 or 31 wherein said amiloride analogue comprises a substitution of the amino group of the 5- position of the pyrazine ring or functional equivalent thereof.
33. The method according to claim 32 wherein said amiloride analogue is HMA or functional equivalent thereof.
34. The method according to claim 33 wherein said HMA comprises the structure:



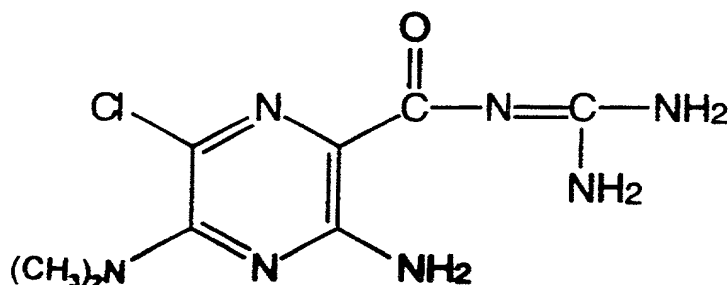
35. The method according to claim 32 wherein said amiloride analogue is DMA or functional equivalent thereof.
36. The method according to claim 35 wherein said DMA comprises the structure:



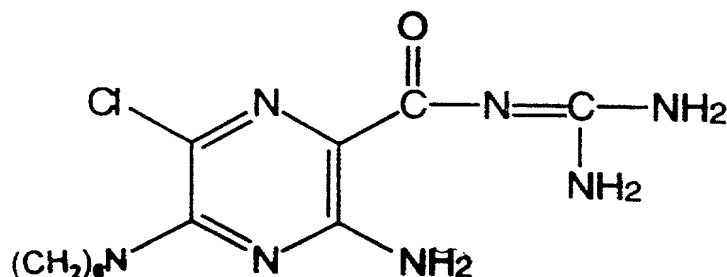
37. Agent for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity.
38. The agent according to claim 37 wherein said Vpu ion channel functional activity is mediation of HIV replication.
39. The agent according to claim 38 wherein said agent is an amiloride analogue or functional equivalent thereof.
40. The agent according to claim 39 wherein said amiloride agent is HMA or functional equivalent thereof.
41. The agent according to claim 40 wherein said HMA comprises the structure:



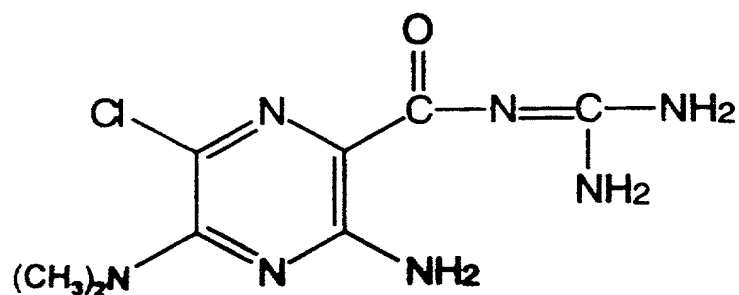
42. The agent according to claim 39 wherein said amiloride agent is DMA or functional equivalent thereof.
43. The agent according to claim 42 wherein said DMA comprises the structure:



44. A pharmaceutical composition for use in reducing, retarding or otherwise inhibiting Vpu ion channel functional activity said composition comprising an agent as defined in accordance with any one of claims 1 to 21 and one or more pharmaceutical acceptable carriers and/or diluents.
45. The pharmaceutical composition according to claim 44 wherein said agent is an amiloride analogue or functional equivalent thereof.
46. The pharmaceutical composition according to claim 45 wherein said amiloride analogue is HMA or functional equivalent thereof.
47. The pharmaceutical composition according to claim 46 wherein said HMA comprises the structure:



48. The pharmaceutical composition according to claim 44 wherein said amiloride analogue is DMA or functional equivalent thereof.
49. The pharmaceutical composition according to claim 48 wherein said DMA comprises the structure:



1/10

\*  
MQPIPIVAIVVAVIIAIVWVSIVIIEYRKILRQKIDRLIDLRIERAEDSGNESEGEISALVEMGVEMGHHPDWDDDL  
80 \* + - - -

Figure 1a

2/10

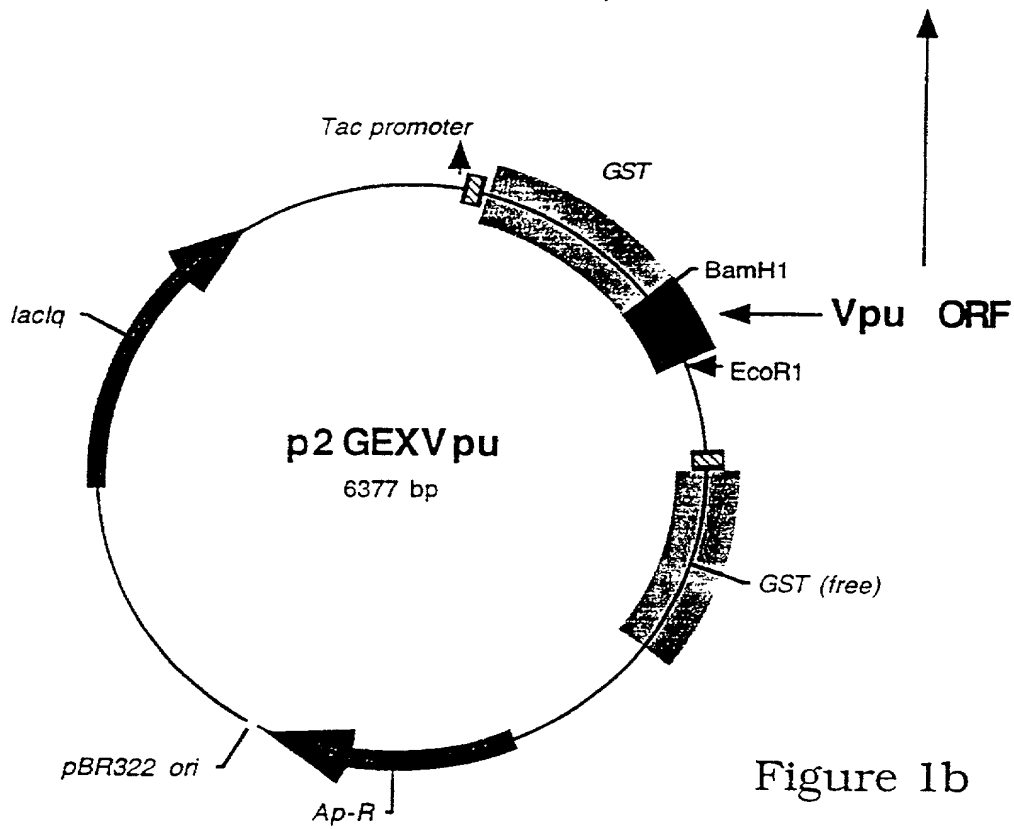


Figure 1b

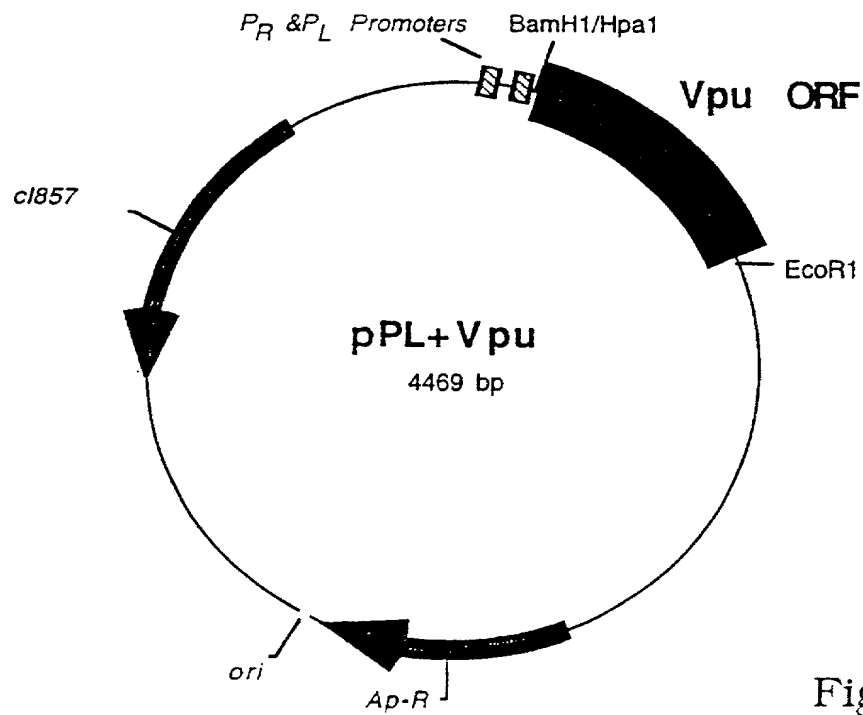


Figure 1c

3/10

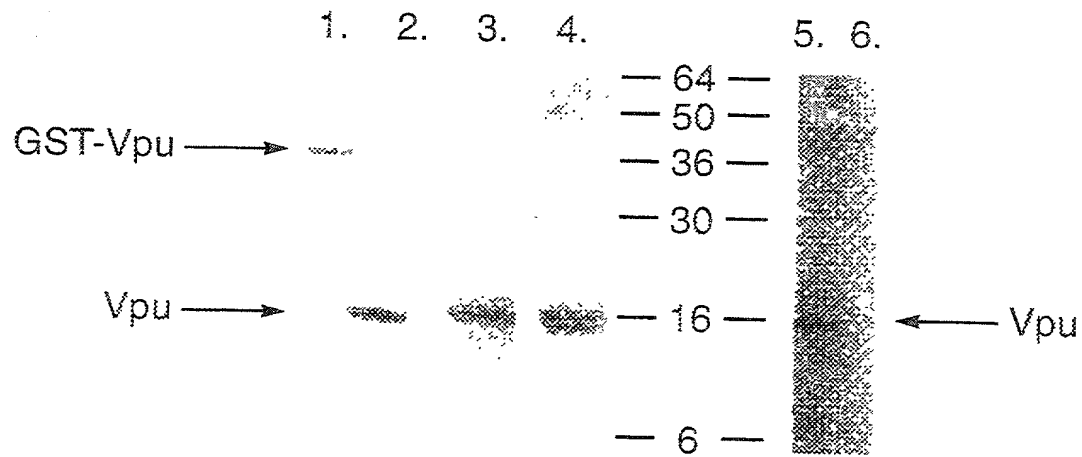


Figure 2a

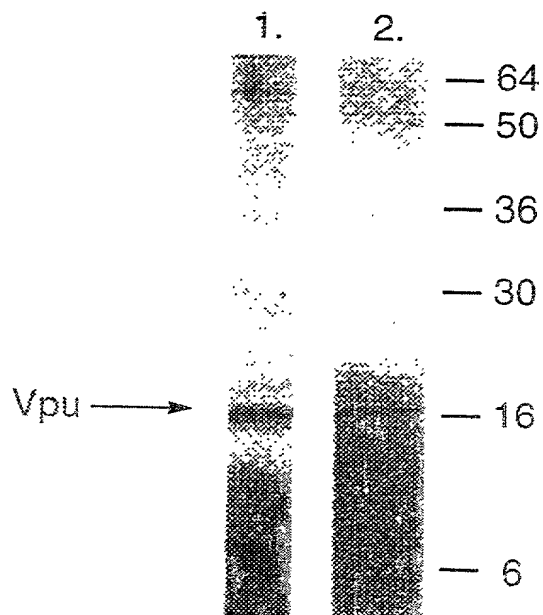


Figure 2b



4/10

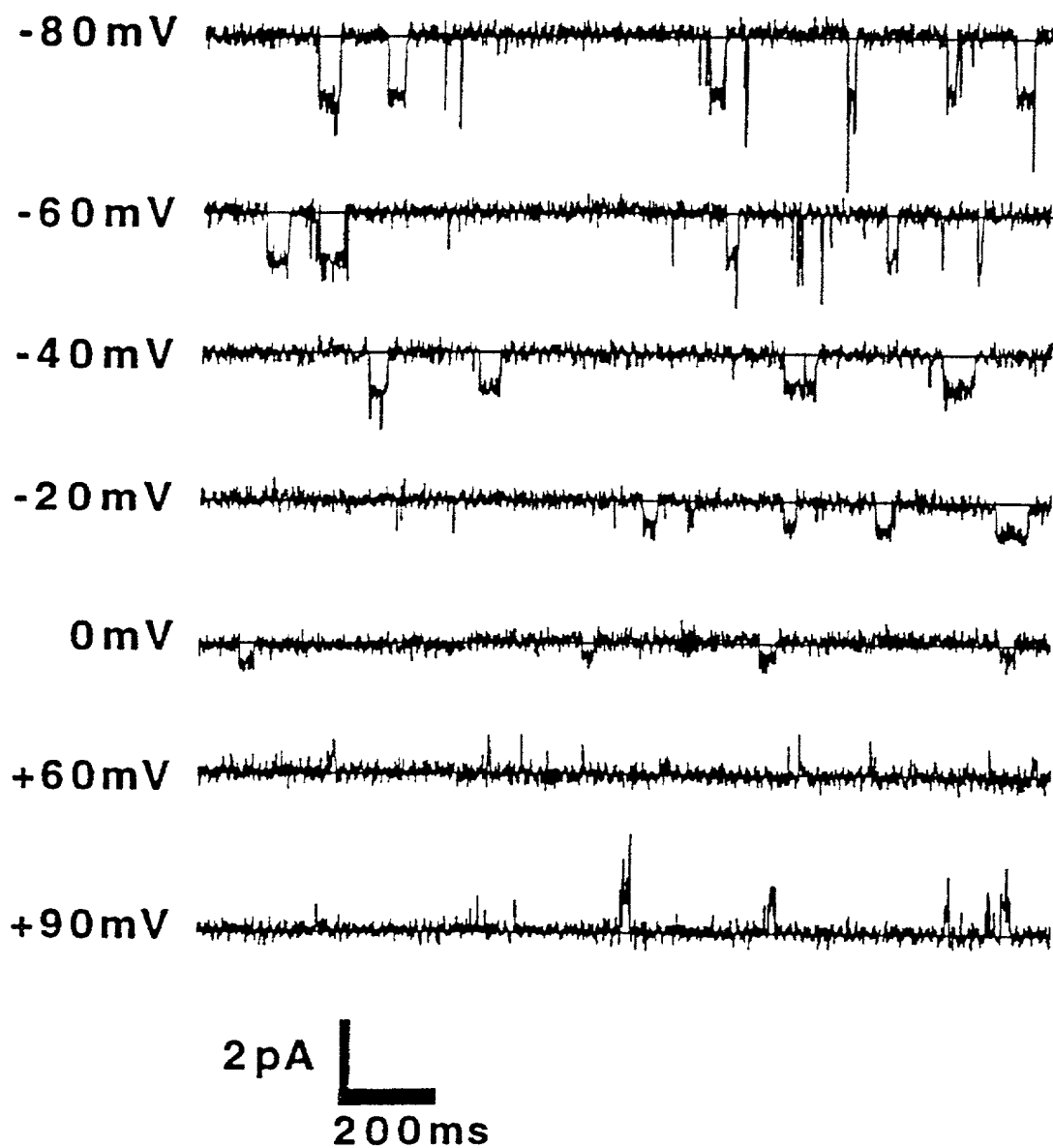


Figure 3a

5/10

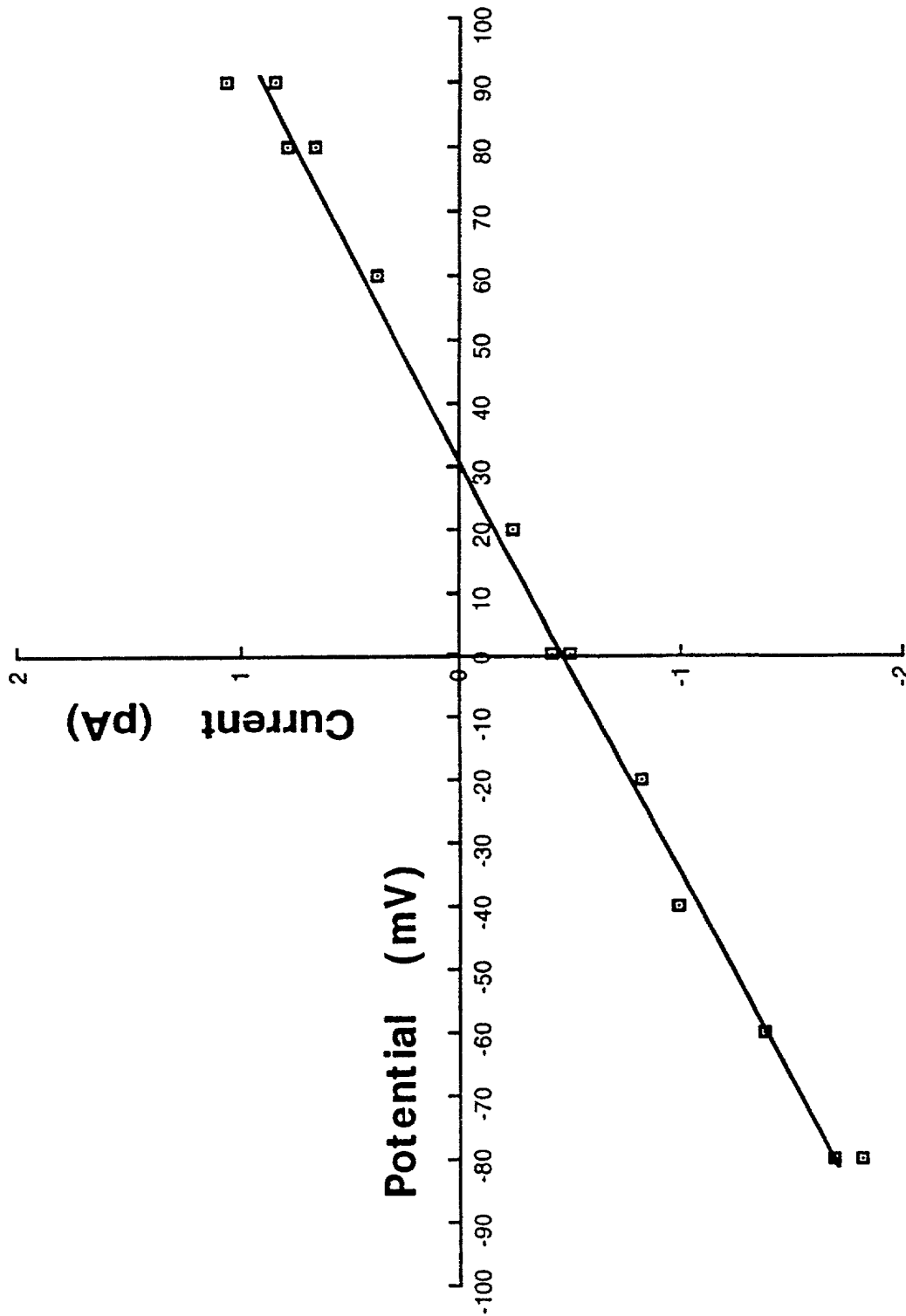


Figure 3b

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Figure 4a

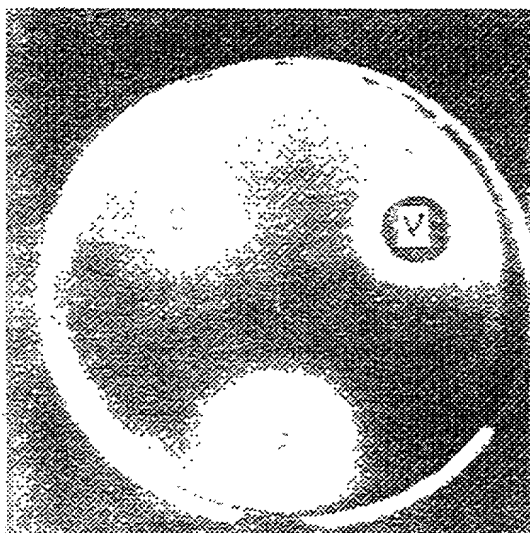
37°C, Pro<sup>-</sup> plate

Figure 4b

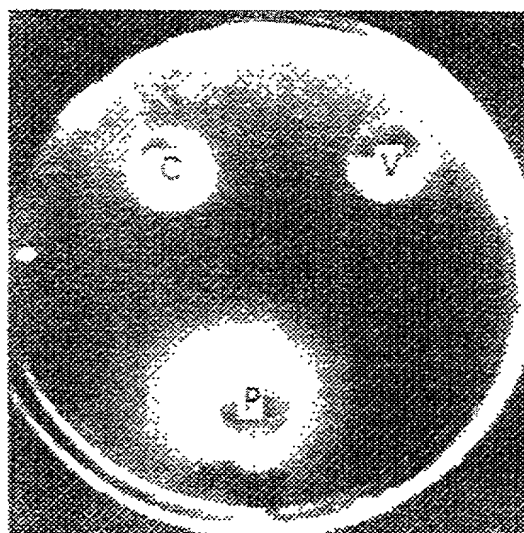
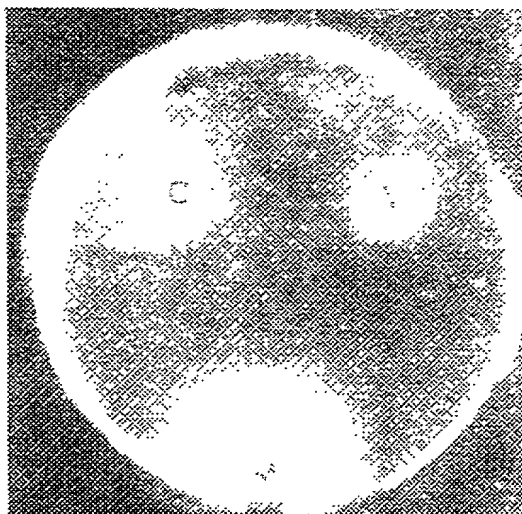
30°C, Pro<sup>-</sup> plate

Figure 4c

37°C, Met<sup>-</sup> plate

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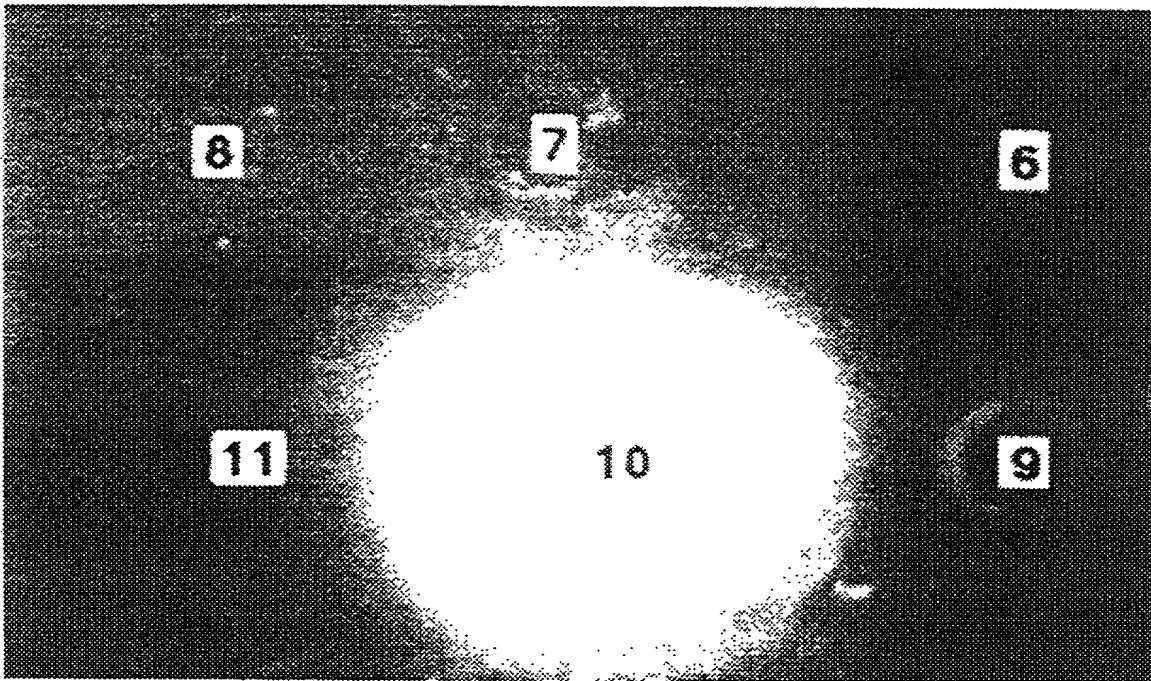


Figure 5

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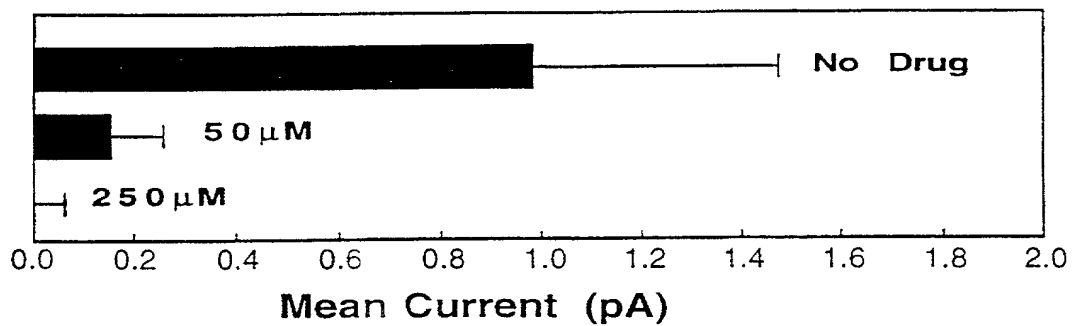
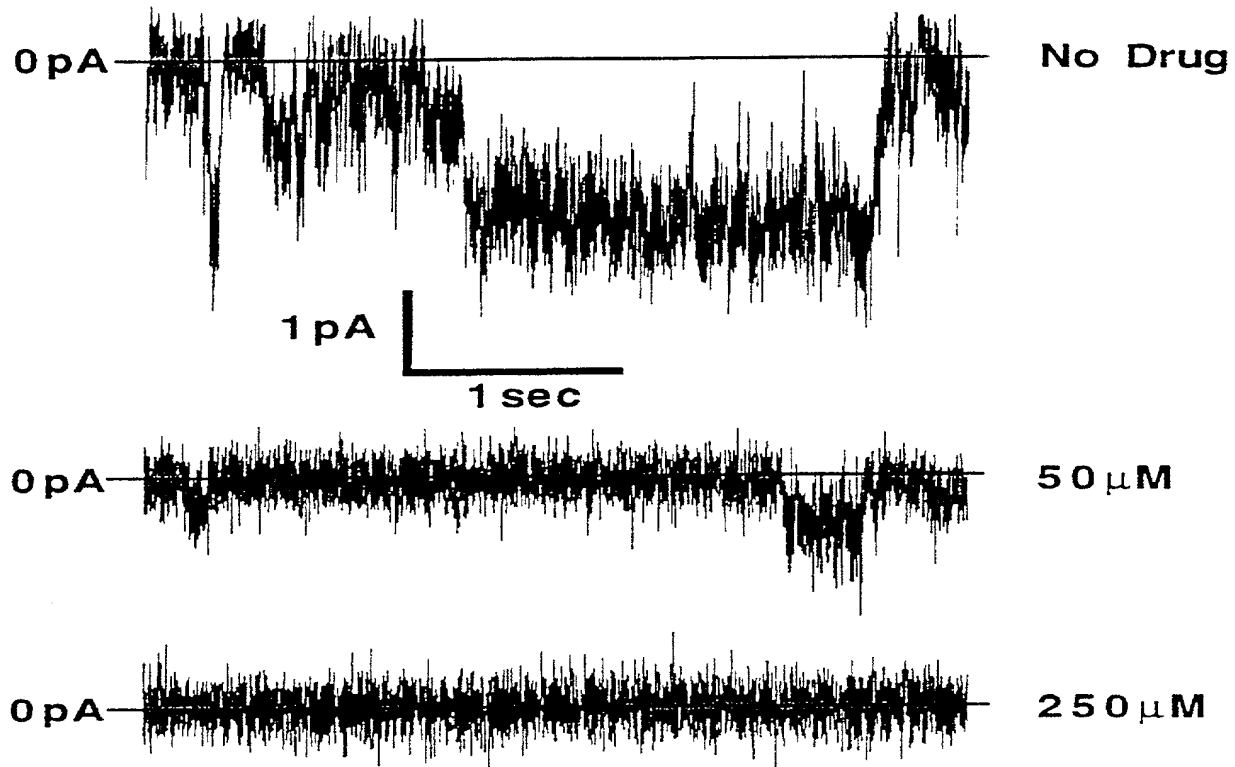
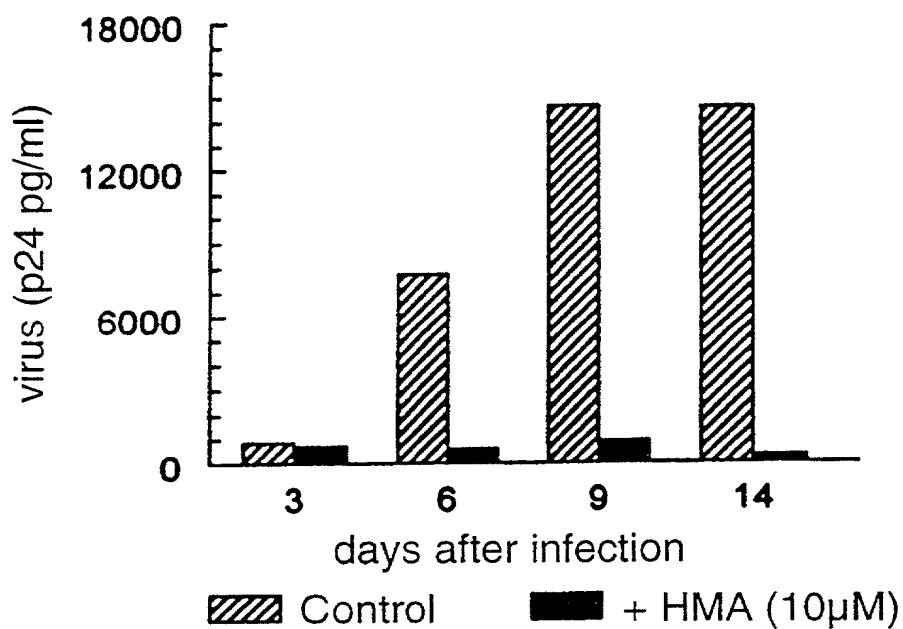


Figure 6

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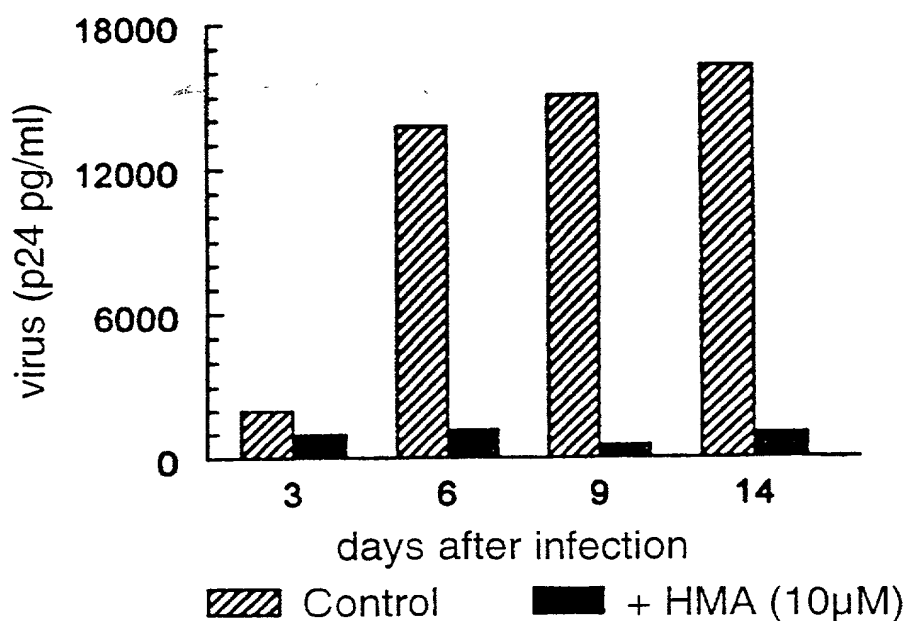
## Monocytes

Figure 7a



## Macrophages

Figure 7b



10/10

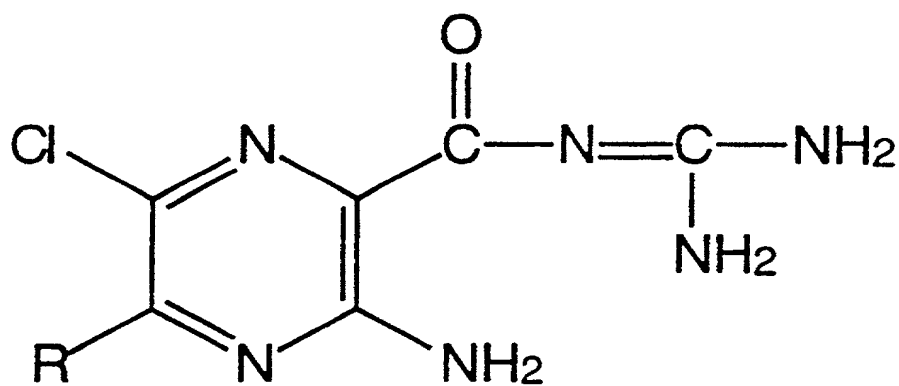


Figure 8

#8

**COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY**  
 (Includes Reference to Provisional and PCT International Applications)

Attorney's Docket No.

032505-010

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**A METHOD OF MODULATING ION CHANNEL FUNCTIONAL ACTIVITY**

the specification of which (check only one item below):

☐ is attached hereto.

was filed as United States application

Number 09/807,277

on April 11, 2001

and was amended

on \_\_\_\_\_ (if applicable).

☐ was filed as PCT international application

Number \_\_\_\_\_

on \_\_\_\_\_

and was amended

on \_\_\_\_\_ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(e) of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. §119:**

COUNTRY (if PCT, indicate "PCT")	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. §119
PCT	PCT/AU99/00872	12, October, 1999	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Australia	PP6464/98	12, October, 1998	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below.

\_\_\_\_\_  
(Application Number)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Number)

\_\_\_\_\_  
(Filing Date)



**COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D)**  
(Includes Reference to Provisional and PCT International Applications)

Attorney's Docket No.

032505-010

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose to the Office all information known to me to be material to the patentability as defined in Title 37, Code of Federal Regulations §1.56, which became available between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. §120:

U.S. APPLICATIONS		STATUS (check one)		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED
PCT APPLICATIONS DESIGNATING THE U.S.				
PCT APPLICATION NO.	PCT FILING DATE	U.S. APPLICATION NUMBERS ASSIGNED (if any)		
PCT/AU99/00872	October 12, 1999	Not Yet Assigned		x

I hereby appoint the following attorneys and agent(s) to prosecute said application and to transact all business in the Patent and Trademark Office connected therewith and to file, prosecute and to transact all business in connection with international applications directed to said invention:

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Address all telephone calls to: Mary Ann Dillahunt at (650)622-2330.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (CONT'D)  
(Includes Reference to Provisional and PCT International Applications)

Attorney's Docket No.

032505-010

*Graeme B. Cox* 10/5/01

1-00

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*[Signature]*

DATE

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Australian

POST OFFICE ADDRESS

Same

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CITIZENSHIP

Australian

POST OFFICE ADDRESS

Same

2004-06-01 14:22

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WO 00/21538

PCT/AU99/00872

- 1 -

## SEQUENCE LISTING

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&lt;120&gt; A METHOD OF MODULATING ION CHANNEL FUNCTIONAL ACTIVITY

&lt;130&gt; 2222985/TDO

&lt;140&gt;

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&lt;160&gt; 4

&lt;170&gt; PatentIn Ver. 2.0

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&lt;212&gt; PRT

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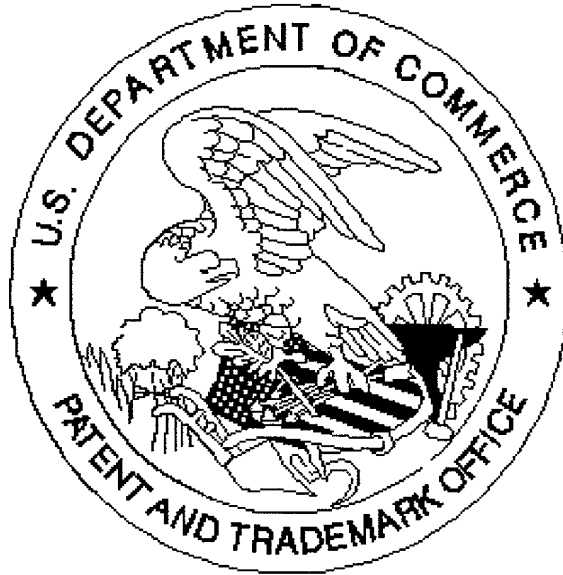
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